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Short-Duration Chickpea Technology: Enabling Legumes Revolution in Andhra Pradesh, India

International Crops Research Institute for the Semi-Arid Tropics

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Short-Duration Chickpea Technology: Enabling Legumes Revolution in Andhra Pradesh, India

by

Cynthia Bantilan, Deevi Kumara Charyulu, Pooran Gaur, Davala Moses Shyam and Jeff Davis

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List of Acronyms

ACIAR	Australian Centre for International Agricultural Research
ANA	Anantapur district
ANGRAU	Acharya N G Ranga Agricultural University
AP	Andhra Pradesh state
APSSDC	Andhra Pradesh State Seed Development Corporation
AY	Actual Yields
BC	Back-ward castes
BCR	Benefit-cost-ratio
CGIAR	Consultative Group on International Agricultural Research
COC	Cost of Cultivation
COP	Cost of production
CP	Chickpea
CVRC	Central Varietal Release Committee
DIIVA	Diffusion and Impact of Improved Varieties in Africa
ED	Elasticity of Demand
ES	Elasticity of Supply
FC	Fixed cost
FF	Fellow Farmer
FGDs	Focus-Group Discussions
FGMs	Focus Group Meetings
GE	Government Extension Agency
GIS	Geographical Information system
GOI	Government of India
HH	Household
HYV	High Yielding Variety
IAS	Impact Assessment Study
IBPGR	International Bureau of Plant Genetic Resources
ICAR	Indian Council of Agriculture Research
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IRR	Internal Rate of Return
KA	Karnataka state
KAD	Kadapa district
KUR	Kurnool district
LGP	Length of growing period
LS	Local Seed Traders

MAHA	Mahabubnagar district
MC	Marginal Cost
MED	Medak district
MH	Maharashtra state
MIT	Massachusetts Institute of Technology
NA	Non-Adopters
NARS	National Agricultural Research System
NIZ	Nizamabad district
NPV	Net Present Value
NRM	Natural Resources Management
NSC	National Seeds Corporation
NY	Normal Yield
PDS	Public Distribution System
PE	Production Environment
PRM	Prakasam district
Qtl	Quintal
SAT	Semi-Arid Tropics
SC	Scheduled Castes
SD	Short Duration
SFCI	State Farm Corporation of India Ltd
SPIA	Standing Panel on Impact Assessment
SSEA	South and South East Asia
ST	Scheduled Tribes
SW	Switchers
ATC	Average Total Cost
TC	Total Cost
TL	Tropical Legumes
TRIVSA	Tracking Improved Varieties in South Asia
UCR	Unit cost reduction
UC	Unit Cost
VC	Variable cost
VLS	Village Level Studies

Conversions used

$ US = Rs.55

Qtl = 100 kg

M ton = 1000 kg

Acre = 0.404 ha

1. Introduction

This study presents the success story of the adoption and diffusion of improved chickpea short-duration varieties in southern India. The experience in the state of Andhra Pradesh particularly exemplifies evidences that adoption of technologies significantly enhanced agricultural productivity and total welfare gains in both traditional and non-traditional chickpea growing regions. As part of a global initiative to assess the impacts of legumes research in the CGIAR, this study supported by the Standing Panel on Impact Assessment (SPIA) contributes to generating more reliable information on key aspects of adoption and diffusion as well as gaining better insights and deeper understanding of the impacts of varietal change.

This study conducted a comprehensive adoption survey to generate reliable data on adoption and better understand the diffusion process as well as quantify the direct impacts on productivity, unit cost reduction and welfare gains from chickpea research. The focus is to measure the economic impact of improved short-duration chickpea varieties, and at the same time gain a deeper understanding of the underlying adoption and diffusion process.

Study rationale

The last five decades saw chickpea production undergoing tremendous change in terms of area shift from northern India (cooler, long-season environments) to southern India (warmer, short-season environments), particularly beginning in the period of 1975-1990 with the expansion of the wheat and rice industry. New chickpea varieties adapted to warmer, short-season environments are bringing increasing prosperity to southern India and offering hope for farmers elsewhere in the semi-arid tropics (SAT). To appreciate the chickpea revolution in southern India, we need to review the chickpea evolution in the country during the last four decades.

Northern India, with its long winters, has suitable climate for chickpea cultivation. However, the expansion of irrigation in the Indo-Gangetic Plains, the development of high yielding varieties (HYV) of wheat and rice during the green revolution period, and the accompanying high input agriculture gradually displaced chickpea to marginal rainfed areas and led to chickpea cultivation being largely replaced by wheat and other cash crops.

Now large areas of chickpea crop in the semi-arid tropics most often experience short winters, terminal moisture stress and heat stress, wilt disease and pod borer problems at the reproductive stages, particularly in southern states of India. During the 1964-65 cropping season, chickpea was planted on 5.14 million hectares in northern India; it is now planted on only 0.73 million hectares (2010-11). During the same period in southern India, the cropped area has gone up significantly from 2.05 m ha to 5.56 m ha. This tremendous shift in cropped area happened due to the introduction of high yielding short-duration chickpea varieties which are resistant to Fusarium wilt disease (Figure 1.1). Overall, the total chickpea area in the country has gone up marginally from 7.5 to 7.6 m ha between 1971-75 and 2006-10.

In the above context, it is compelling to systematically document the adoption, diffusion and impact of improved chickpea technologies in southern India. This specific success story is positive evidence that adoption of technologies can enhance production of chickpea in other regions of South Asia and sub-Saharan Africa, where currently yield levels remain low. A comprehensive quantification of

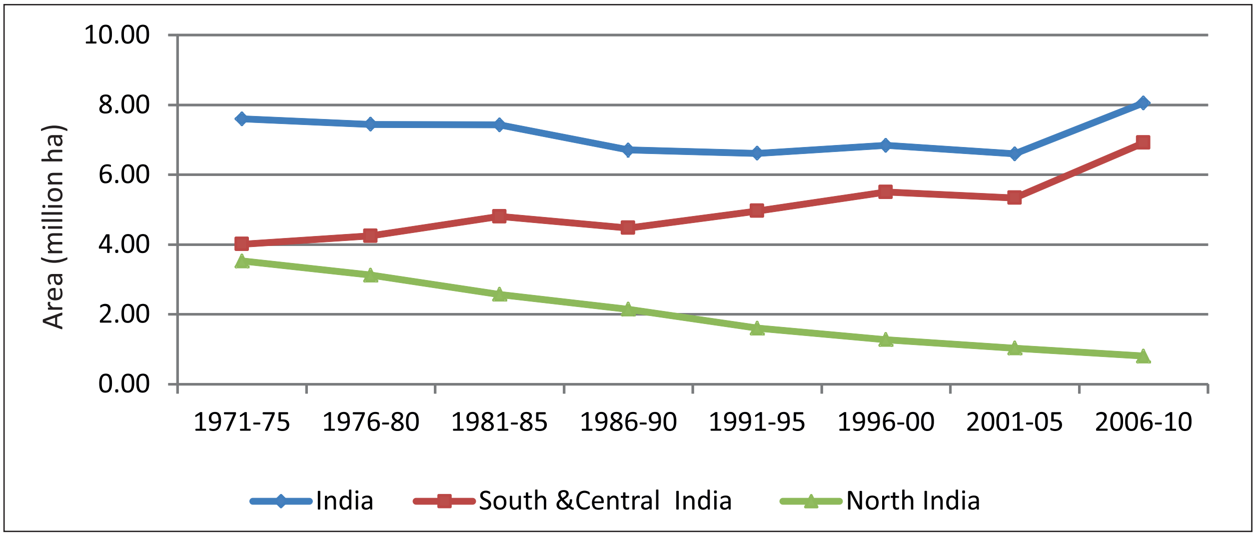

Figure 1.1. Shifts in chickpea area from North to South and Central India.

the research benefits at farm level is timely, particularly in Andhra Pradesh as the outcome of the analysis will showcase the impact of chickpea improved technology in India. The chickpea revolution in Andhra Pradesh would be a suitable case to unravel many inter-linked issues in technology adoption and agricultural intensification. Some relevant issues that can be further investigated using this data and analysis are socio-economic, institutional and policy drivers for technology adoption, farm-level responses (input use, land allocation, soil and water conservation, crop and natural resource management (NRM) technologies, mechanization etc), household welfare and sustainable intensification of SAT agriculture.

Objectives of the study

The overall objective is to document the 'silent chickpea revolution in Andhra Pradesh.' Specifically, it aims to address the following three major objectives:

1. Develop and apply new advances in methodology for assessing adoption and impacts of improved agricultural technologies;
2. Track the adoption of chickpea high yielding short-duration improved cultivars in AP;
3. Assess the farm-level benefits of adoption of chickpea improved technologies; and estimate the welfare impacts for the state of Andhra Pradesh and India.

Scope of the study

This comprehensive impact assessment study (IAS) has a detailed adoption analysis and on-farm survey to fully understand the various dimensions of impacts and generate the best possible data. The study has been designed to understand and measure the adoption, diffusion and impact of chickpea short-duration improved cultivars in the state of Andhra Pradesh through a representative primary survey and suitable decision tree protocol. Quantification of farm-level welfare benefits experienced by chickpea growing farmers is determined by examining various scenarios of technology adoption: namely, a) replacement of old improved cultivars (Annigeri) with adoption of new improved cultivars (such as JG 11, KAK 2 and Vihar among others); as well as b) switching over by non-chickpea growing farmers (eg, farmers traditionally growing other crops such as cotton, tobacco, sorghum, groundnut, chillies and others) to new improved short-duration chickpea cultivars. Overall, the study aims to understand the substantial preferences for chickpea cultivation over other crops in this state, the pattern of chickpea varietal adoption and replacement, productivity gains at farm-level, unit-cost reductions and its impact on welfare. The influence of socio-economic, institutional and policy variables on the extent of adoption will also be studied. Further, the behavioural changes in own land allocation, leasing-in land, soil and water management, input-use application and mechanization etc. will be documented in relation to technology adoption.

Plan of the study

This report is organized in 8 chapters. The first two chapters introduce and give a background of the industry and research context of the study. It discusses the importance of chickpea in the world and in India and its historic trends using a temporal analysis covering more than four decades of data on chickpea area, production and productivity. Chapter 3 introduces the global chickpea research domains used in targeting chickpea research. This is complemented by the spatial analysis of bio-physical data – soil, rainfall and length of growing period regimes – which may be influencing chickpea productivity and the diffusion of chickpea short-duration cultivars across various agro-ecologies. It also systematically documents the research and development process and research timeline with specific focus on chickpea short-duration cultivars. Corresponding research and development costs from research started in 1978 up to the release and dissemination of the new short-duration cultivars in southern India are systematically documented. Chapter 4 elucidates the methodology for estimating the welfare benefits and the conceptual framework underlying it. This gives the theoretical basis of the welfare estimates which encompass a multi-country perspective and captures the direct benefits from technology adoption in targeted regions as well as the spillover research benefits globally. The tools and methods used to better understand and document technology adoption are discussed in the following chapter to fully understand the impacts including a number of specific testable hypotheses linking the introduction of the new early maturing varieties in southern India to insightful dimensions of impact. This component of the study illustrates some innovative approaches for getting best possible data for the impact assessment study. Chapter 5 describes the survey details including the sampling framework for the comprehensive study. The process of development of varietal identification protocols and survey instruments are discussed.

The results of the adoption study are presented in Chapter 6. The primary survey results are first featured to reflect the socio-economic profile of chickpea traditional and non-traditional growers in Andhra Pradesh. Deeper insights on the adoption and diffusion process are achieved by disaggregating the data further to analyze the diverse diffusion patterns across cultivars and across districts and more critically to incorporate in the impact analysis the welfare gains and losses of adopters and non-adopters and analyze the benefits of various types of adopters. Chapter 7 presents the summary of the key parameter estimates drawn from Chapter 6 and other sources of the minimum data set for assessing welfare gains. In particular, the summary list draws from the field insights on costs and returns in crops cultivation and unit-cost reductions due to adoption of new technology. The estimated welfare benefits are quantified and presented for Andhra Pradesh and India. Finally, Chapter 8 presents the summary and conclusions about the study.

2. Background to Research

Chickpea industry context

Chickpea (*Cicer arietinum L.*) is the largest pulse crop grown in India and the second largest food legume in the world. It occupies around 15% of total pulse area globally and is cultivated in almost 52 countries (FAOSTAT 2012). South and South East Asia (SSEA) together contribute about 88 and 86% shares in global area and production respectively (Table 2.1). Chickpea, like other pulse crops traditionally grown in many parts of the world, has multiple functions in the traditional farming systems especially in many developing countries. As well as being an important source of human food and animal feed, it also helps in the management of soil fertility, particularly in drylands (Sharma and Jodha 1984).

India ranks first in terms of chickpea production and consumption in the world (both at almost 70%). Currently, chickpea covers 35% of total pulse area and constitutes nearly 47% of total pulse production in India (GOI 2012). The long term macro trends (1980-2010) in India indicate that the cropped area has slightly increased and registered a growth rate of 0.25% (Figure 2.1). But, the production and productivity have increased significantly with exhibited annual growth rates of 1.3 and 1.04% respectively during the same period (Table 2.2).

Table 2.1. Chickpea regional distribution, 2012.

Region	No. of countries	Area (m ha)	% share	Production (m ton)	% share	Productivity (kg/ha)
World	52	11.98	100.00	10.92	100.00	911.20
Asia	16	10.65	88.92	9.36	85.76	878.82
Africa	14	0.53	4.44	0.52	4.73	970.98
Australia	1	0.50	4.17	0.60	5.51	1204.00
N America	7	0.24	1.97	0.36	3.29	1523.28
Europe	14	0.06	0.51	0.08	0.71	1280.70

Source: FAOSTAT 2012

Table 2.2. All-India chickpea area, production and yield growth rates (%).

Period	Total area	Total production	Yield
1980-1985	1.23	3.76	2.53
1986-1990	2.67	4.99	2.24
1991-1995	6.65	7.85	1.13
1996-2000	-7.33	-8.73	-1.49
2001-2005	2.84	3.06	0.20
2006-2010	3.60	8.25	4.29
1980- 2010	0.25	1.30	1.04

Source: Ministry of Agriculture and Cooperation 2012

The major six states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh, together contribute more than 90% of area and production of chickpea in India (Table 2.3). However, the growth rate during the last four decades (1970-2010) in area, production and productivity is distinctly higher in Andhra Pradesh when compared with other states. The productivity in Andhra Pradesh has increased substantially from 853 kg per ha in 1996-97 to 1308 kg per ha by 2009-10 due to the widespread adoption of improved high-yielding short-duration cultivars. While the linear trend line computed for productivity for the period, 1950-51 to 2010-11, for the whole country indicated the productivity increased by about 5 kg per year (Figure 2.2).

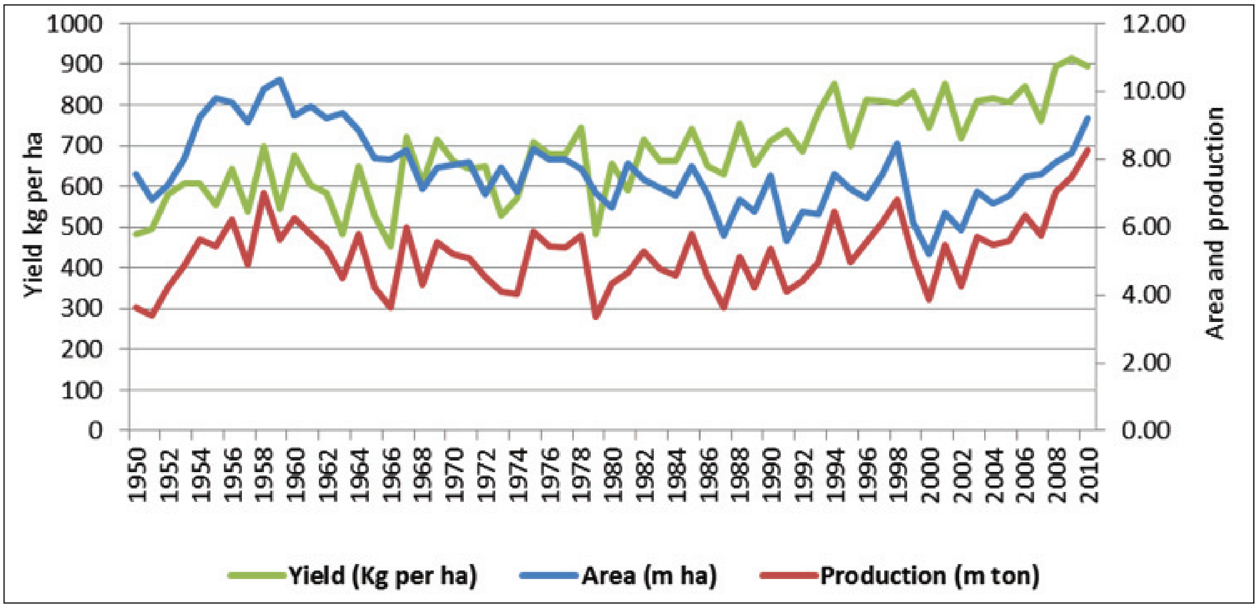

Figure 2.1. Chickpea area, production and productivity in India, 1980-2010.

Source: Ministry of Agriculture and Cooperation 2012

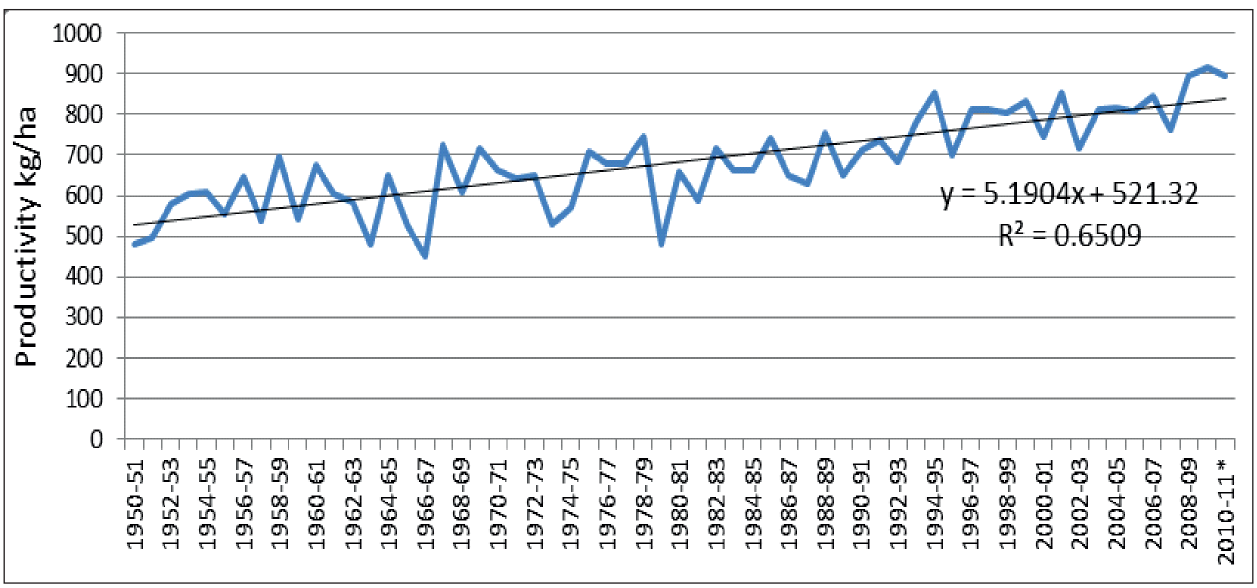

Figure 2.2. Productivity of chickpea in India, 1950-51 to 2010-11.

Source: Directorate of Economics and Statistics GOI

Table 2.3. Performance of chickpea across major states in India, 1966-2010.

	Area in ’000 ha		Production ’000 tons		Productivity (kg/ha)	
States	1966-1968	2008-2010	1966-1968	2008-2010	1966-1968	2008-2010
Andhra Pradesh	77.0 (0.99)	614.6 (7.27)	18.3 (0.40)	810.0 (10.64)	238	1317
Maharashtra	366.3 (4.70)	1289.3 (15.33)	112.3 (2.42)	1060.0 (14.00)	305	815
Madhya Pradesh	1569.7 (20.15)	3014.0 (35.79)	733.0 (15.82)	2925.3 (38.56)	469	972
Gujarat	45.7 (0.59)	162.0 (1.91)	14.0 (0.30)	170.0 (2.20)	337	1032
Punjab	503.5 (6.46)	2.66 (0.03)	398.7 (8.61)	3.16 (0.04)	775	1197
Uttar Pradesh	2297.3 (29.49)	580.0 (6.90)	1387.5 (29.94)	533.3 (7.04)	607	923
Bihar	289.2 (3.71)	209.33 (2.01)	173.0 (3.73)	60.1 (0.77)	598	1042
Rajasthan	1144.7 (15.40)	1307.7 (15.56)	722.3 (15.58)	1036.7 (13.70)	620	760
Karnataka	176.7 (2.52)	886.33 (10.52)	73.0 (1.83)	533.7 (7.05)	430	600
India	7788.3 (100.00)	8420.0 (100.00)	4630.0 (100.00)	7590.0 (100.00)	594	902

Note: Figures in the parenthesis indicate percentage to the column total

Source: Ministry of Agriculture and Cooperation 2012

Temporal analysis of chickpea area, production and productivity

As highlighted earlier, the state-wise growth in chickpea area, production and productivity during the last four decades (1970-2010) are presented in Table 2.4. The highest growth in chickpea area was observed in Andhra Pradesh (Figure 2.3) followed by Karnataka, Maharashtra and Madhya Pradesh between 1970 and 2010. Rajasthan and Uttar Pradesh exhibited negative growth trends in the area during the same. Similar patterns were also experienced for chickpea production in these states. The productivity enhancement was most conspicuous in Andhra Pradesh when compared to other states in India. However, the increase in yield was significant during last two decades due to peak adoption of improved cultivars (Figure 2.5). On average the productivity has increased only 8.2 kg per ha per annum from 1970 to 1990 while the same increased at 46.5 kg per ha per year between 1991 and 2010 in Andhra Pradesh (Figures 2.4 & 2.5).

Table 2.4. Long-term chickpea trends in major states, 1970-2010 (Area: ’000 ha, Production: ’000 tons and Yield: kg/ha).

State	Item	1971-1980	1981-1990	1991-2000	2001-2010	1971-2010
	Area	64.7	58.2	125.7	490.8	184.9
	Prod.	22.2	26.0	95.0	616.9	190.0
Andhra Pradesh	Yield	339.5	434.6	744.2	1242.5	690.2
	Area	60.8	97.2	101.2	149.3	102.1
	Prod.	41.6	73.6	71.5	136.3	80.7
Gujarat	Yield	683.0	735.4	669.8	853.5	735.4
	Area	158.9	196.6	315.9	622.0	323.4
	Prod.	61.7	74.1	157.3	343.4	159.1
Karnataka	Yield	383.7	381.5	485.3	541.3	448.0
	Area	417.8	544.5	716.6	1072.6	687.9
	Prod.	141.0	237.3	414.8	771.1	391.1
Maharashtra	Yield	330.0	423.2	570.3	691.6	503.8
	Area	1571.2	1513.6	1510.4	1081.9	1419.3
	Prod.	1073.9	1018.0	1082.5	759.2	983.4
Rajasthan	Yield	672.4	664.8	695.2	694.9	681.8
	Area	1843.9	2219.4	2453.8	2706.7	2305.9
	Prod.	1065.8	1512.8	2125.5	2455.1	1789.8
Madhya Pradesh	Yield	583.1	680.0	862.6	902.3	757.0
	Area	1731.8	1415.8	957.7	687.2	1198.1
	Prod.	1510.9	1180.1	832.5	619.3	1035.7
Uttar Pradesh	Yield	850.7	834.8	870.4	895.7	862.9
	Area	230.1	177.5	122.5	128.9	119.1
	Prod.	136.2	145.1	115.9	79.0	164.7
Bihar	Yield	596.8	819.1	951.7	961.1	119.1
	Area	320.0	103.3	16.7	4.4	111.1
	Prod.	268.5	66.0	13.7	4.2	835.3
Punjab	Yield	825.2	674.0	848.7	993.4	835.3

District-wise performance of chickpea in Andhra Pradesh

The historical trends (1990-2010) in district-wise area and production trends are summarized in Figures 2.6 and 2.7. Kurnool followed by Prakasam hold the lion’s share of cropped area in the state. Anantapur and Kadapa are in expanding mode rapidly since 2005. Overall, all the major study districts are stagnated in their cropped area or even exhibited a slight downward trend during 2010. Similarly, the production trends are much higher in the case of Kurnool followed by Prakasam and Anantapur districts. A more erratic pattern in production was observed in the case of Kadapa, Nizamabad, Medak and Mahabubnagar districts.

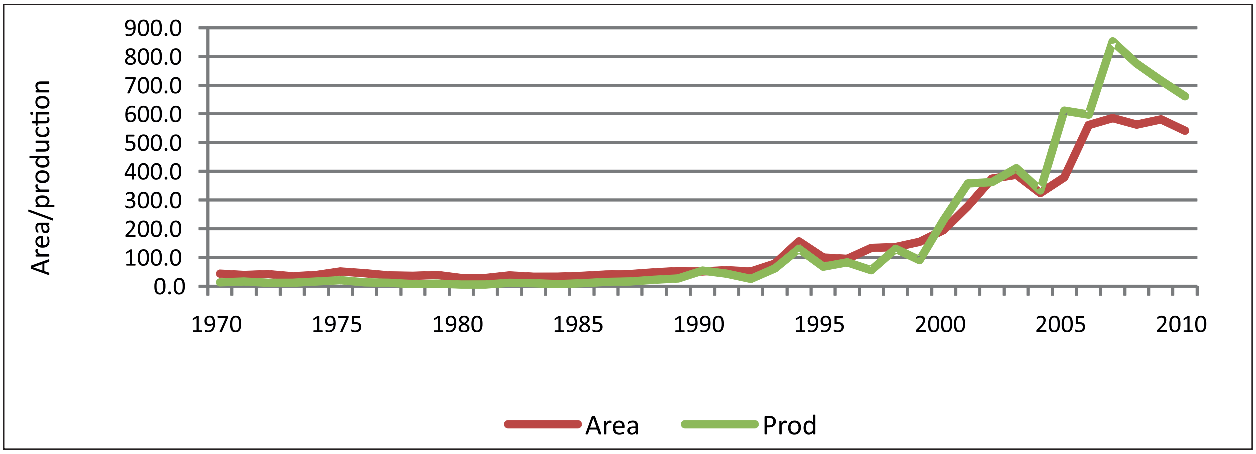

Figure 2.3. Chickpea area ('000 ha) and production ('000 tons) in Andhra Pradesh, 1970-2010.

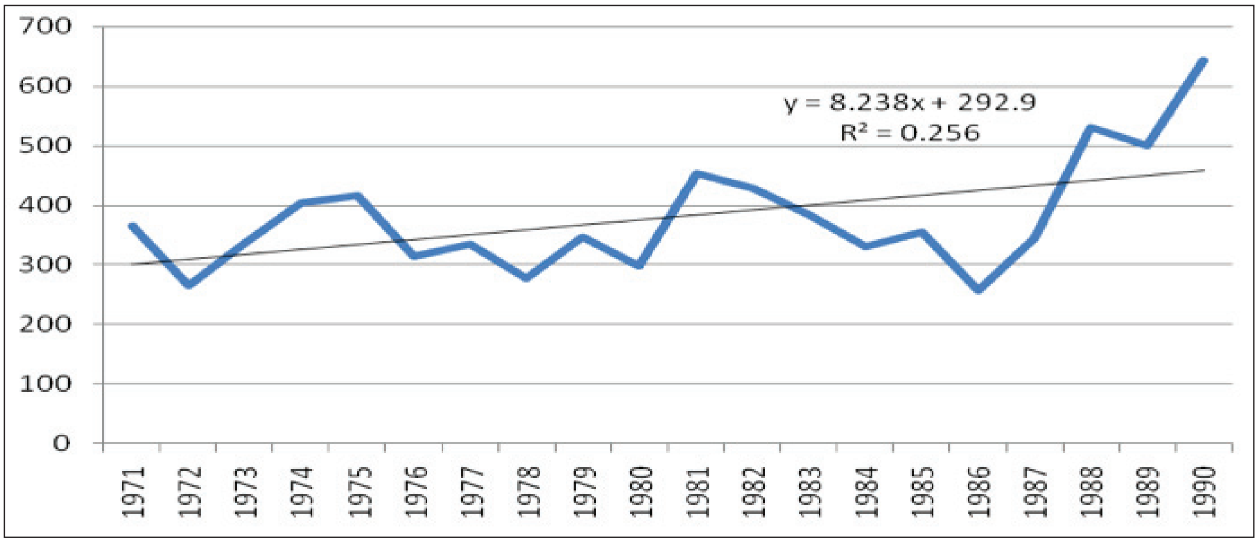

Figure 2.4. Average productivity growth (kg/ha) in Andhra Pradesh, 1970-1990.

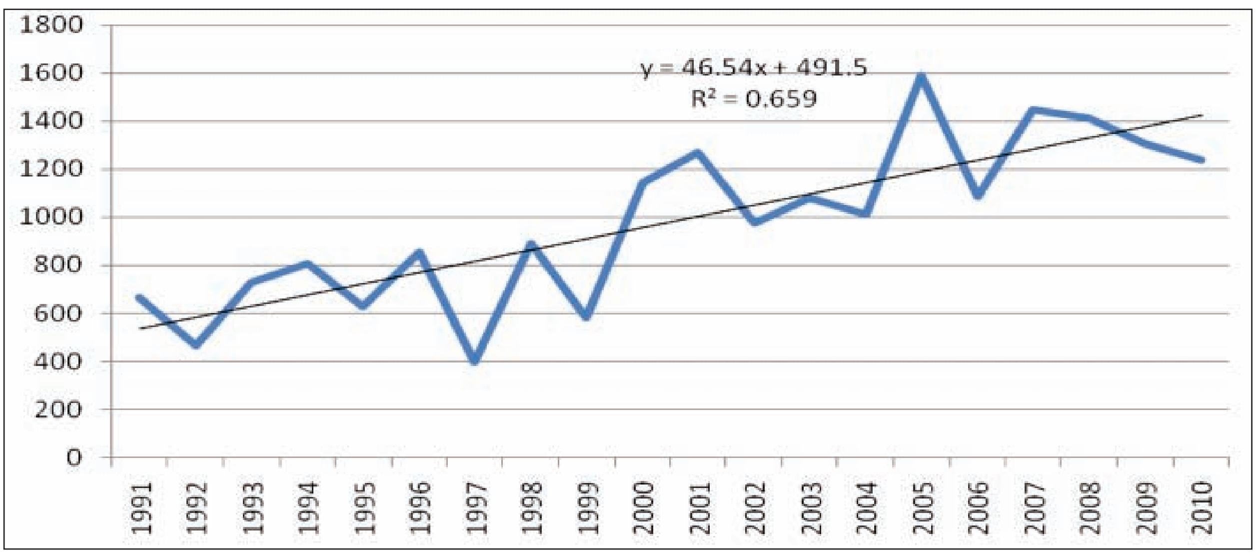

Figure 2.5. Average productivity growth (kg/ha) in Andhra Pradesh, 1991-2010.

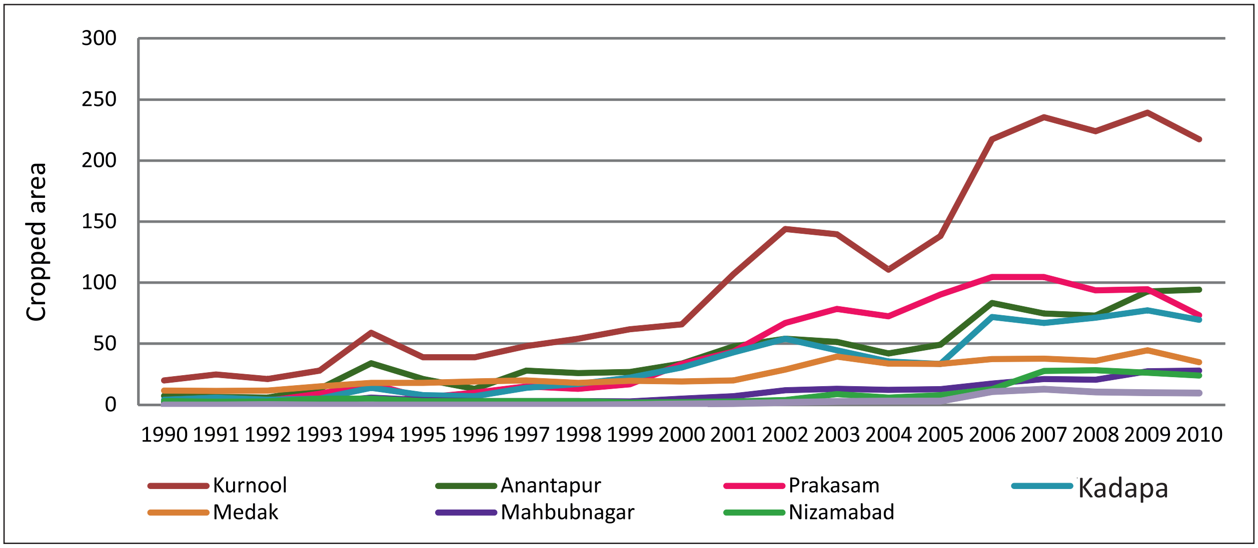

Figure 2.6. Chickpea area ('000 ha) in districts of Andhra Pradesh: 1990-2010.

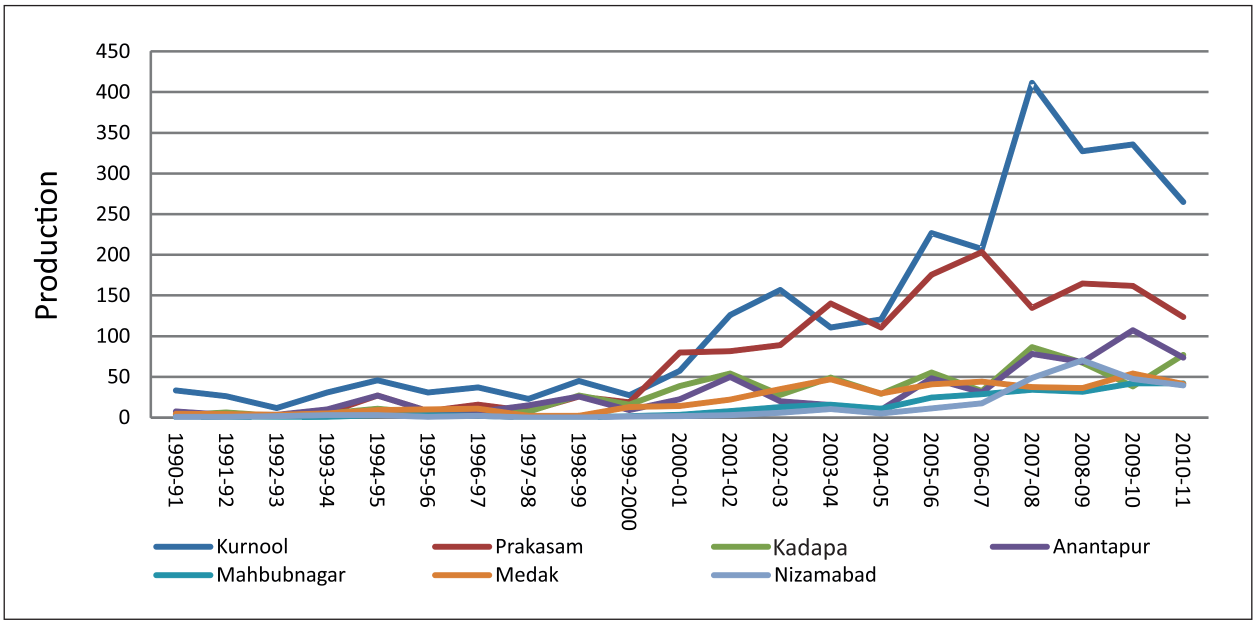

Figure 2.7. Chickpea production ('000 t) in districts of Andhra Pradesh: 1990-2010.

Long term trends of chickpea area show the pace of increase in seven major districts in Andhra Pradesh, and even indicating new up-coming areas in the vertisols in the northern districts where further diffusion of improved chickpea cultivars in the state is observed (see Table 2.5). Overall, the area expansion was much faster during 1991-2000 when compared to the last decade ie, 2001-2010. Major districts such as Kurnool, Prakasam, Anantapur and Kadapa exhibited slower growth rates in the latest period than the previous. However, new districts such as Nizamabad, Mahabubnagar, Adilabad and Nellore are expanding their area under chickpea significantly. The growth rates in production are also much higher during 1990s than the later period.

Table 2.5. District-wise historical trends of chickpea in Andhra Pradesh.				
	Area growth rate (%)		Production growth rate (%)	
District	1991-2000	2001-2010	1991-2000	2001-2010
Adilabad	8.36	17.06	-	20.44
Nizamabad	-4.46	30.17	-	38.81
Karimnagar	-6.03	0.55	-	-2.06
Medak	5.98	4.99	2.08	4.99
Hyderabad	-	-	-	-
Rangareddy	4.30	3.26	11.59	4.16
Mahabubnagar	7.58	14.50	-	20.30
Nalgonda	-4.39	-	-	-
Warangal	-	2.26	-	-1.64
Khammam	-	-	-	-
Srikakulam	-	-	-	-
Vizianagaram	-	-	-	-
Visakhapatnam	-	-	-	-
East Godavari	-	-	-	-
West Godavari	-	-	-	-
Krishna	-	-	-	-
Guntur	-3.74	8.65	6.45	8.90
Prakasam	24.75	5.76	31.63	5.90
Nellore	-	31.13	-	25.16
Kadapa	21.65	7.47	20.57	6.03
Kurnool	12.17	9.53	5.74	13.61
Anantapur	18.47	8.79	17.46	18.87
Chittoor	-	-	-	-
Total AP	12.40	8.90	15.63	11.40

Table 2.6 summarizes the district-wise recent chickpea trends in Andhra Pradesh for the period 2009-11. Kurnool has major share of area and production in the state followed by Prakasam, Anantapur and Kadapa districts. Medak, Nizamabad and Mahabubnagar are the upcoming districts where the rapid diffusion of short-duration chickpea cultivars has been taking place. Crops such as sorghum, sunflower, coriander and groundnut have been replaced by chickpea because of higher returns and stability in productivity. Among the major players, the productivity was significantly higher in Prakasam followed by Kurnool. This is because of the innovative nature of Prakasam farmers as well as better crop management and climate. Historically Prakasam farmers are migratory, hardworking people and always look for new opportunities in agriculture. Because of availability of better soils and rainfall patterns they replaced labor intensive tobacco crop with short-

duration kabuli types. However, Nizamabad also exhibited the highest productivity levels within new districts group. The detailed discussions about broad shifts in cropping pattern at India level, major chickpea growing states in India and major districts in Andhra Pradesh are presented in Appendix 1.

Table 2.6. Performance of chickpea in major districts of Andhra Pradesh, 2009-11.

District	Area ('000 ha)	Production ('000 tons)	Yield (kg/ha)
Kurnool	227.0 (37)	309.5 (38)	1363.3
Prakasam	87.2 (14)	150.1 (18)	1721.6
Anantapur	86.7 (14)	83.1 (10)	957.7
Kadapa	72.8 (12)	60.8 (7)	835.5
Medak	38.6 (6)	43.7 (5)	1134.0
Nizamabad	26.2 (4)	52.5 (6)	2000.5
Mahabubnagar	25.3 (4)	38.7 (5)	1525.9
Andhra Pradesh	612.3 (100)	807.7 (100)	1319.0

Note: Figures in the parenthesis indicates percentage to the column total.

Historical pattern of chickpea across major districts of Andhra Pradesh

Figure 2.8 depicts the historical pattern of chickpea expansion in major chickpea growing districts of Andhra Pradesh. The quinquennial average shows the steep expansion of chickpea in Kurnool district in early 1980s following by Anantapur, Kadapa and Prakasam districts (also see Table 2.7).

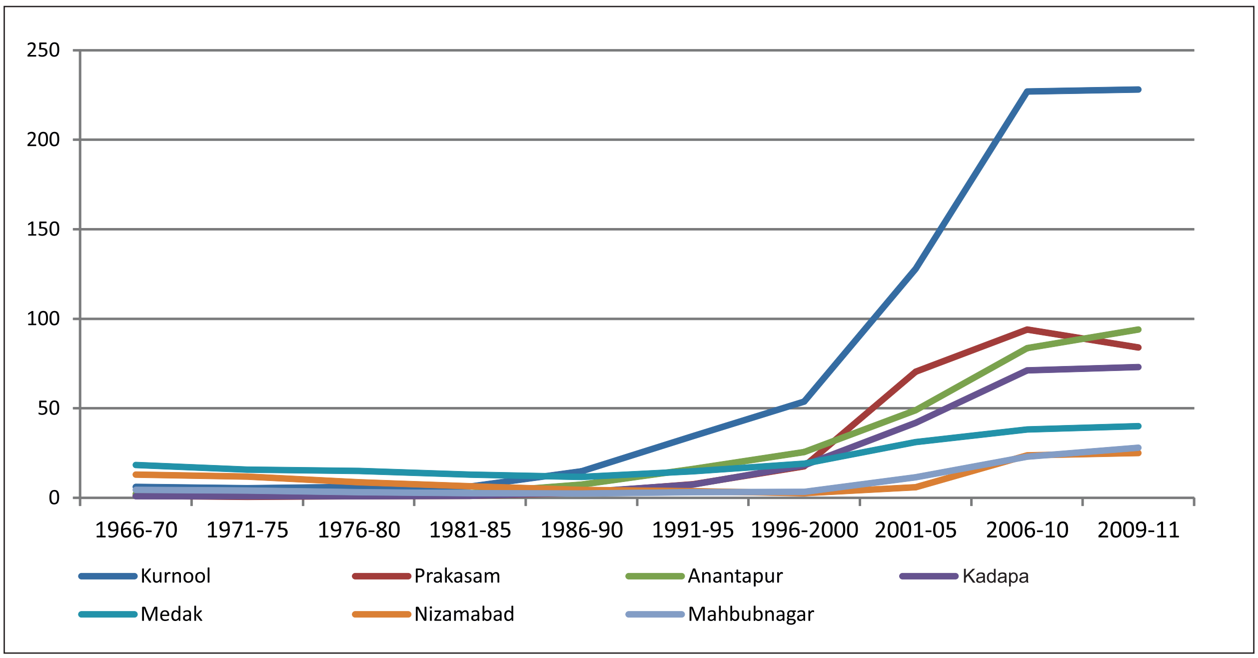

Figure 2.8. Trends in district-level area grown to chickpea in Andhra Pradesh, 1966-2011 ('000 ha).

Table 2.7. Area grown to chickpea from 1966 to 2011 in districts of Andhra Pradesh ('000 ha).

District	1966-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10	2009-11
Kurnool	6	5	6	6	15	35	54	128	227	228
Prakasam	1	1	1	1	3	8	18	70	94	84
Anantapur	2	2	2	3	7	16	26	49	84	94
Kadapa	1	1	1	1	3	7	18	42	71	73
Medak	18	16	15	13	12	15	19	31	38	40
Nizamabad	13	12	9	6	4	4	3	6	24	25
Mahabubnagar	5	4	3	3	2	3	3	11	23	28
Adilabad	5	5	4	3	2	2	3	6	17	11
Guntur	8	5	5	5	3	2	1	8	12	9
Nellore	0	0	0	0	1	0	0	2	11	10
Karimnagar	5	5	3	2	1	1	1	4	3	3
Warangal	2	2	2	1	1	1	1	2	2	2
Krishna	1	1	1	0	0	0	0	0	1	1
Nalgonda	2	2	2	1	0	1	1	0	1	1
East Godavari	1	1	0	0	0	0	0	0	0	0
Visakhapatnam	0	0	0	0	0	0	0	0	0	0
Khammam	1	1	1	1	0	0	0	0	0	0
Srikakulam	0	0	0	0	0	0	0	0	0	0
Chittoor	0	0	0	0	0	0	0	0	0	0
Hyderabad	8	8	7	5	3	0	0	0	0	0
West Godavari	0	0	0	0	0	0	0	0	0	0
Total	80	71	62	52	59	95	147	361	607	609

3. Summary of Research

3.1 Research context

Chickpea research domains and development of improved cultivars

This section describes the process of research and development for chickpea crop improvement in India with specific reference to the development of appropriate cultivars suitable for various agro-ecological zones. The global chickpea research domains are first presented with a description of the domain agro-ecology, the major constraints and countries covered. A more specific description for India is also provided which also identifies the major chickpea producing states within India under each research domain. The historical efforts towards the development of short-duration chickpea cultivars in India are discussed, including a detailed documentation of the research cost. Finally, the complete list of releases of chickpea improved cultivars along with their pedigree information and time line are presented as final products of this research investment.

Broadly, five global chickpea research domains were identified by chickpea crop improvement scientists at ICRISAT. The delineation of chickpea research domains are based on the following critical parameters: latitude, length of growing period, temperature and soil type (ICRISAT MTP 1994). As shown in Figure 3.1, these are (see also in Table 3.1):

- The low latitude (<20°) regions with dry hot climate, vertisol soils and early maturing cultivars are grouped under Research domain-1. The Deccan states of Andhra Pradesh and Karnataka in India, and Central Ethiopia are identified as homogenous regions in this domain.
- Latitudes between 20-25° and early to medium maturing (110-120 days) and vertisols are delineated under Research domain-2. North Ethiopia, Sudan, Kenya, Myanmar and Central India (Maharashtra and part of Madhya Pradesh and Gujarat) fall into this category.
- High latitudes (25-30°) with late maturing (> 120 days) and light soils are classified under Research domain-3. Northwest India (Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar) and Pakistan exhibit these environmental characteristics.
- High latitudes (25-30°), high humidity and medium to late maturing light soils are characterized under Research domain-4. Double cropping system is the particular characteristic of this research domain. Northern India, Nepal and Bangladesh are included in this domain.
- Very cool high latitude (>30°) and late maturing climates are defined as Research domain-5. Turkey, Syria, Mexico and USA are the dominant countries identified under this climate.

The development of chickpea improved cultivars in these five research domains needs specific emphasis on crop improvement and breeding objectives.

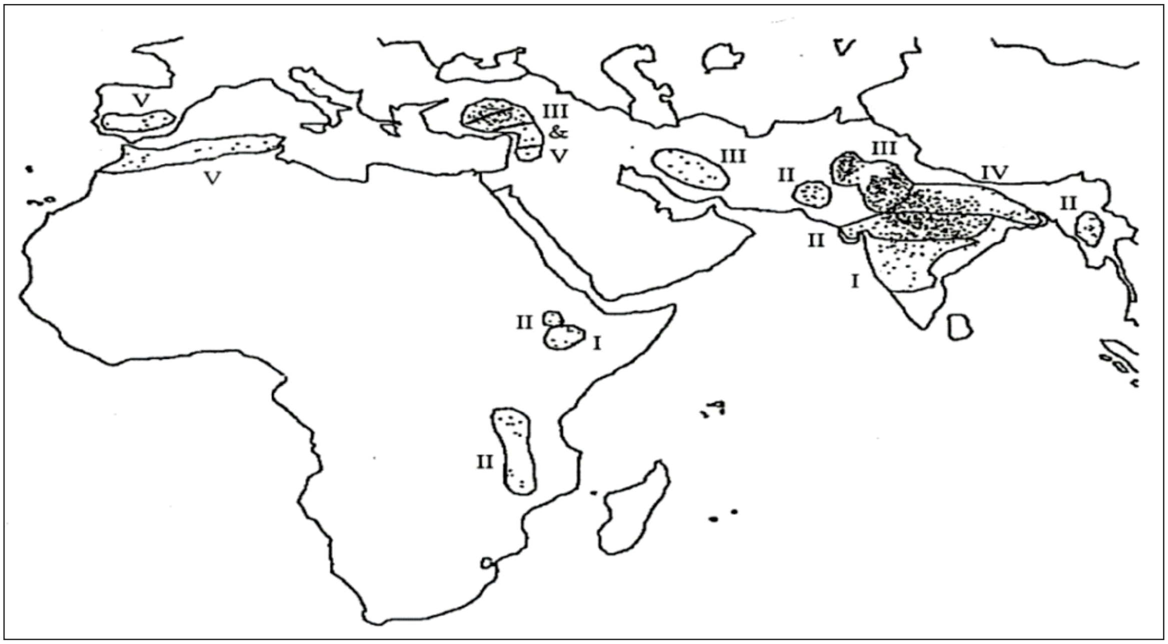

Figure 3.1. Global chickpea research domains.

Table 3.1. Description of global chickpea research domains.

Research domain	Description	Major constraints	Locations
CP-I	Low latitude (below 20°), dry hot, early maturing vertisols	Soil-borne diseases, drought and heat	E Africa (C Ethiopia), India (Deccan and S India)
CP-II	20-25° latitude, early to medium maturing, single cropping system vertisols with LGP 110-120 days	Soil-borne diseases, drought	E Africa (N Ethiopia, Kenya, Sudan), Central India, Myanmar, Mediterranean (spring-sown)
CP-III	25-30° latitude, dry, cooler than II, late maturing than II, double cropping system light soils with LGP > 120 days	Foliar diseases (Ascochyta Blight), low temperature, drought	NW India, Pakistan, Mediterranean (spring-sown)
CP-IV	25-30° latitude, cooler than III. Medium-to-late-maturing types. High humidity, double cropping system (follows rainy season crop), light soils	Foliar diseases (Botrytis gray mold)	N India, Nepal and Bangladesh
CP-V	Above 30° latitude. Winter sowing, late-maturing, very cool	Cold, Ascochyta blight, Orobanche (parasitic weed)	Mediterranean (Turkey, Syria, Israel, Greece, N Africa, Spain, Portugal), Mexico and USA

CP = Chickpea; LGP = length of growing period.

Source: ICRISAT MTP 1994. Refinement of these research domains for chickpea globally is reported in another paper using spatial analysis and GIS tools (Nedumaran and Bantilan 2013; forthcoming).

The above domains align seamlessly with the research domains used by the ICAR research system for chickpea as shown in Figure 3.2 where they characterized three zones based primarily on the crop duration.

More specifically, the chickpea research domains in India are characterized into three types based on the crop duration. Broadly, they are short (85-100), medium (100-120) and long (120-140) duration types (Figure 3.2). States Andhra Pradesh and Karnataka fall under short-duration with hot climate and early maturing types. Around 17-20% of the India's chickpea area is situated in this climate. Maharashtra, parts of Madhya Pradesh and Gujarat states are grouped as medium-maturing climates. Nearly 40-50% of country's chickpea crop distribution is spread over in this environment. Certain parts of Madhya Pradesh, Uttar Pradesh, Rajasthan and Bihar states have high latitude vertisols with double cropping systems and are categorized as long maturing types. About 25-30% of the chickpea cropped area is grown in this climate.

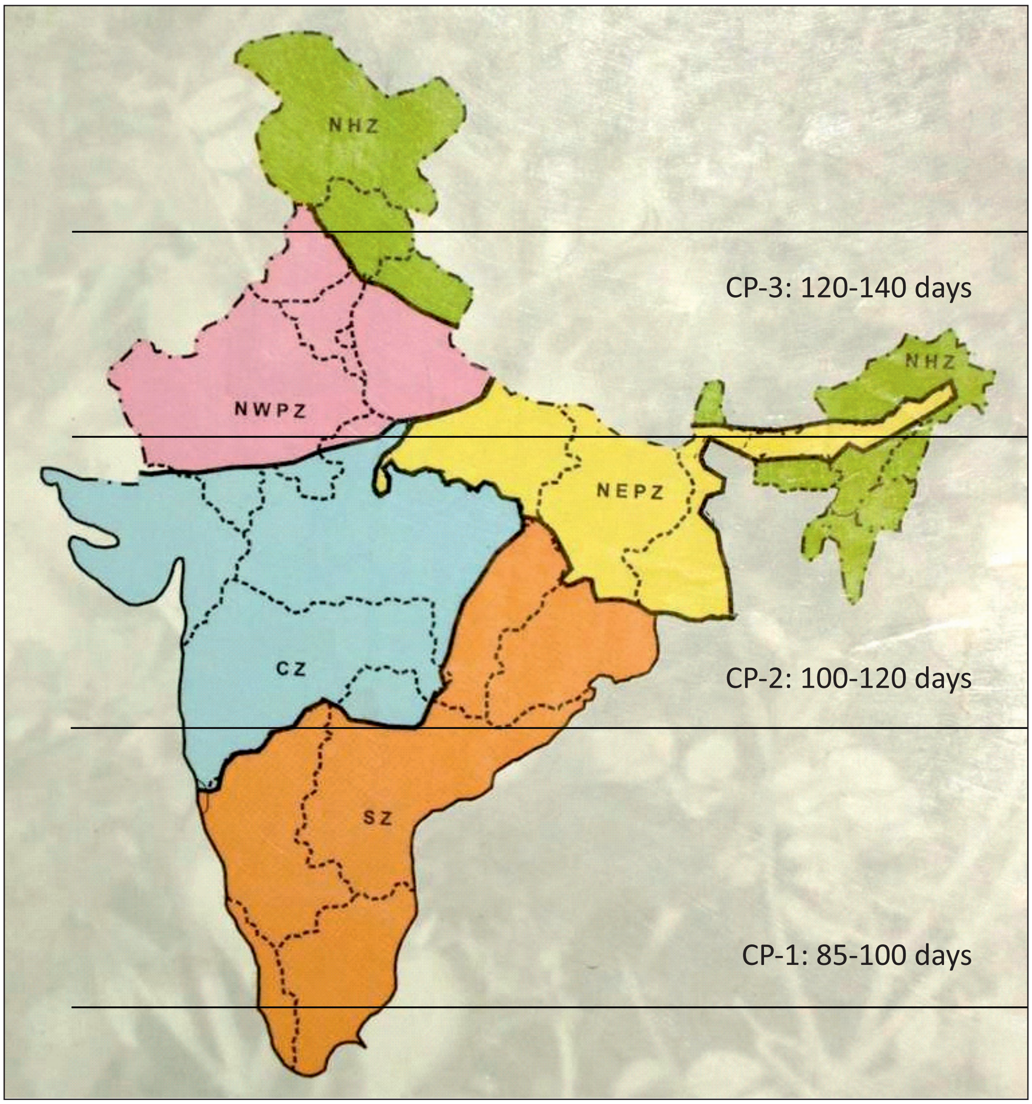

Figure 3.2. Chickpea crop durations across India.

Spatial analysis using more detailed data identifying targeted research domains in the state of Andhra Pradesh

As shown above, the delineations of the targeted chickpea research domains are essentially determined by the latitude, length of growing period, temperature, irrigation and soil type of the above regions. For the state of Andhra Pradesh, spatial analysis using these parameters assists in identifying the specific homogeneous zones for chickpea adaptation and possible zones of diffusion. As it still remains an empirical question whether the area grown to chickpea has stabilized and already reached its ceiling level, a spatial analysis of the above parameters using data for Andhra Pradesh will guide us to answer this question. This may lead to confirmation of the following empirical questions: Has the ceiling level of chickpea area in Andhra Pradesh been reached? Or are there possible remaining new niche areas for further rapid diffusion of chickpea short-duration improved cultivars, eg, Mahabubnagar, Medak and Nizamabad districts or possible potential in upper Adilabad district and rice fallows in Krishna and Godavari basins? Or have the irrigation investments in the neighboring districts expanded to present more remunerable crops or cropping systems which fetches more income to farmers other than chickpea?

Spatial distribution of rainfall in Andhra Pradesh

Chickpea is a postrainy season crop and is highly influenced by rainfall. The distribution of rainfall during the cropping season also influences the productivity significantly. The annual average normal rainfall of the study districts ranges from 600 to 1000 mm. The highest normal rainfall was recorded in Nizamabad followed by Medak, Prakasam and Kadapa districts. The average normal rainfall for Kurnool and Mahabubnagar districts was around 600-650 mm. The lowest annual normal rainfall of 550 mm was observed in Anantapur district. It was observed that the risk of crop failure due to lack of sufficient moisture for the cultivation of chickpea was highest in Anantapur districts, followed by Kurnool and Mahabubnagar.

Figure 3.3 presents the distribution of chickpea area in Andhra Pradesh overlaid with different normal rainfall regimes (Isohyets) in a calendar year. The GIS image provides systematic information on diverse climatic situations existing for chickpea cultivation in Andhra Pradesh. The seven prominent chickpea cultivating districts in the state exhibited different ranges of rainfall patterns. This information may be used to measure the extent of risk in chickpea cultivation in that particular region/district. In general, the quantum and variability of rainfall will have a definite influence on chickpea yields in those mandals/districts. However, the high concentrated chickpea growing mandals fall in 500-700 mm rainfall range; these are Kurnool, Kadapa, Anantapur and Mahabubnagar districts. Prakasam has a slightly better rainfall regime of around 850 mm. Medak and Nizamabad districts receive the best rainfall pattern of around 1000 mm.

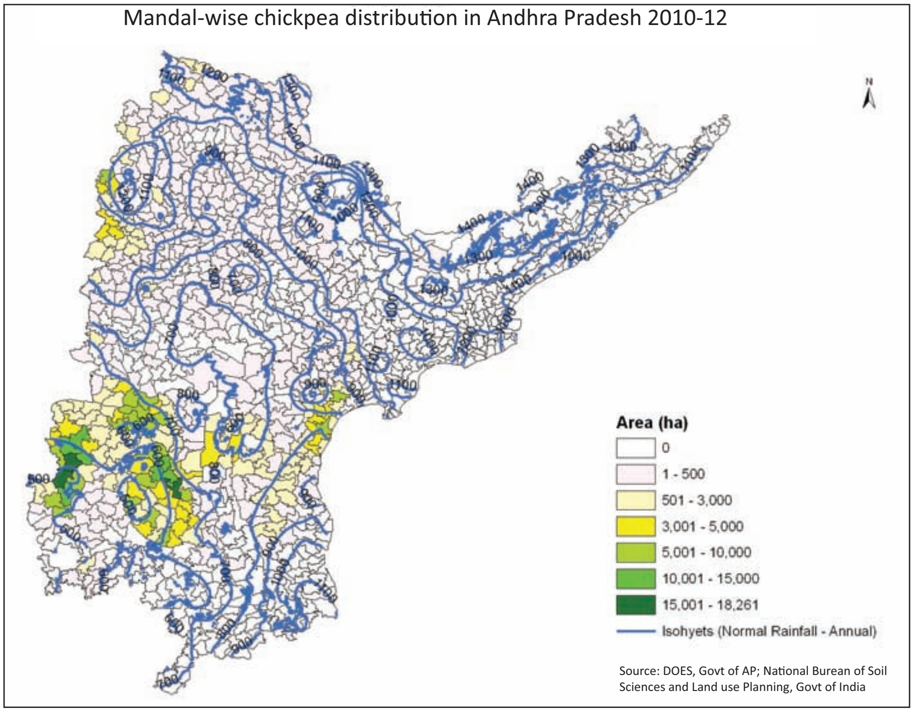

Figure 3.3. Chickpea area distribution under different rainfall regimes of AP.

Table 3.2. District-wise rainfall deviations over normal, 2001-10 (in mm).

Year	ANT	KUR	PRM	KAD	MED	MAH	NIZ
Normal rainfall	552	670	871	700	868	604	1035
2001	110	48	-135	181	-176	52	-165
2002	-165	-111	-295	-232	-309	-61	-351
2003	112	89	-230	-327	-109	-4	-203
2004	-38	-80	-233	-98	-332	-183	-320
2005	220	131	11	155	-31	283	149
2006	-118	-78	-47	-183	-25	-45	33
2007	184	339	12	306	-225	176	-177
2008	212	-10	48	0	6	-31	-102
2009	23	89	-260	-93	-276	119	-367
2010	204	154	438	207	56	151	45

The detailed secondary data analysis of rainfall (normal) across major chickpea growing districts of Andhra Pradesh is summarized in Table 3.2. The normal rainfall of Nizamabad stood on the top followed by Prakasam, Medak, Kadapa, Kunrool, Mahabubnagar and Anantapur districts. Out of the ten years, Medak exhibited the maximum number (8 times out of 10) of negative rainfall deviations years from the normal. Prakasam, Kadapa, Medak and Nizamabad districts also showed deficit rainfall from the normal rainfall in six out of 10 years. This pattern clearly indicates the extent of risk in rainfed agriculture, especially with crops such as chickpea which germinate on residual soil moisture, but also need enough moisture during the reproductive phase. Any moisture stress during the terminal stage reduces the crop yields drastically. So the quantum of rainfall in a particular district may be sometimes misleading, and its distribution (especially northeast monsoon) throughout the season is more crucial for chickpea performance. Relatively, the negative deviations in total rainfall from the normal were lower in Anantapur and Kurnool districts during the study period.

Length of growing periods (LGP) in chickpea cultivation

Length of growing period (LGP) is another crucial bio-physical parameter which determines the crop choices in a particular region/district. The choice between cropping systems depends on the availability of days. Figure 3.4 presents the distribution of different LGPs in Andhra Pradesh overlaid with chickpea area distribution. The figure provides the clear evidence of the extent of chickpea distribution in two major LGP windows in Andhra Pradesh. They are Window-1: 75-89 days and Window-2: 90-119 days. However, traces of chickpea are also present in the ‘less than 74 days’ window and the ‘120-149 days’ window. More than 50% of cropped area falls in the 90-119 days window. The majority of Anantapur and part of Kurnool districts have crop growth windows of 75-89 and less than 74 days. This clearly indicates the high risk to chickpea growth due to terminal moisture stress. A large portion of Kurnool and all of Kadapa falls into the window of 90-119 days. This window is more suitable for chickpea cultivation as it matures in about 90-100 days. Prakasam district has a longer LGP period ranging from 120-149 days (two crops in a calendar year). Overall, the majority of chickpea farmers in the state follow the ‘fallow-chickpea’ cropping system. However,

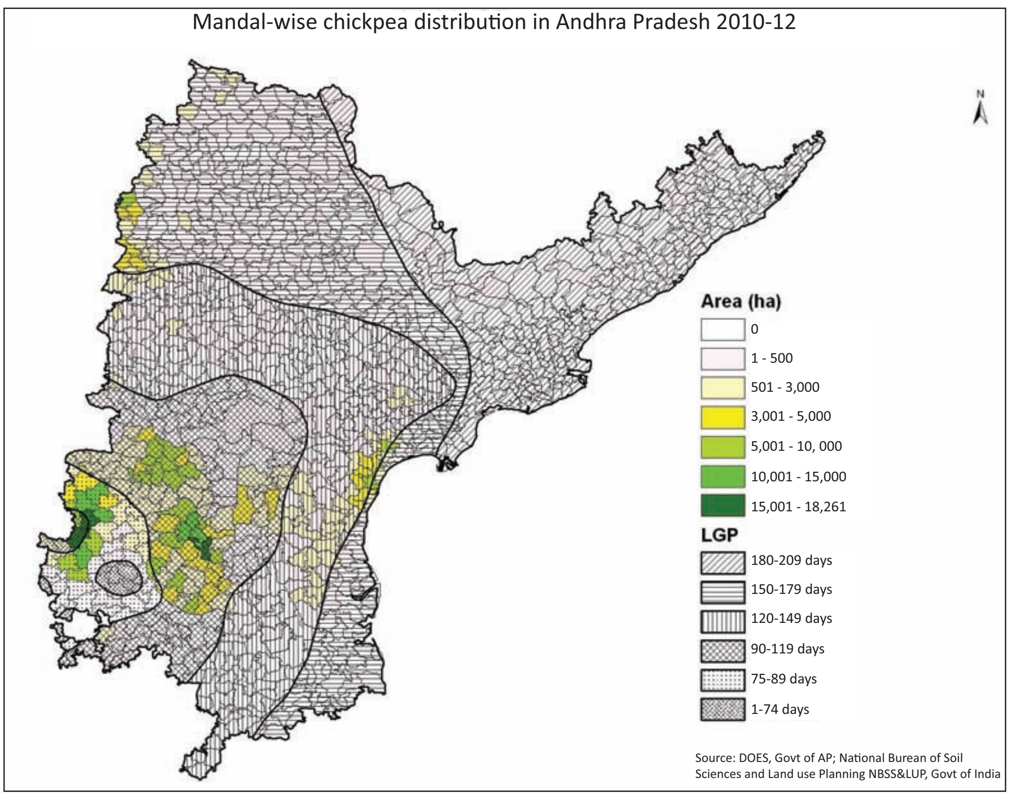

Figure 3.4. Distribution of chickpea area under different LGPs (days).

the new upcoming districts (Medak and Nizamabad) have longer LGPs of 150-179 days. There is significant potential to diffuse chickpea into the rice fallows where the LGP is about 180-209 days.

Spatial distribution of soil types in Andhra Pradesh

Chickpea requires cooler climates (< 35°C) and can only be grown in postrainy (rabi) conditions. Since the crop thrives on retention/residual soil moisture, soil type is the important determinant for cultivating chickpea crop. In general, black soils have more soil moisture retention capacity than any other type. Deep to medium or light textured black cotton soils (also called vertisols) are most suitable for chickpea cultivation. Chickpea can also be grown on alfisols with access to little irrigation facilities. However, red, sandy and chalky soils are not found suitable for chickpea cultivation.

Figure 3.5 presents the spatial distribution of soil types in Andhra Pradesh overlaid with chickpea area. It is observed that alfisols, inceptisols and vertisols are pre-dominant in this state. It seems that the spread of chickpea crop was limited to only vertisols and alfisols in Andhra Pradesh. The figure indicates the distribution of chickpea cropped area exactly falls under these two soil types which supports the hypothesis that for cultivation of chickpea soil type (vertisol or alfisol) is a pre-condition.

The above analysis was further pursued to inquire about the adoption and diffusion of short-duration improved cultivars in Andhra Pradesh. There are bigger patches of vertisols on the upper part of the map (Adilabad and Nizamabad) and on the right hand side (Krishna and Godavari districts). This indicate a scope and potential for further spread of crop in the state.

Further details about extension of diffusion bounded by access to irrigation and beyond Andhra Pradesh has been furnished in appendix 2.

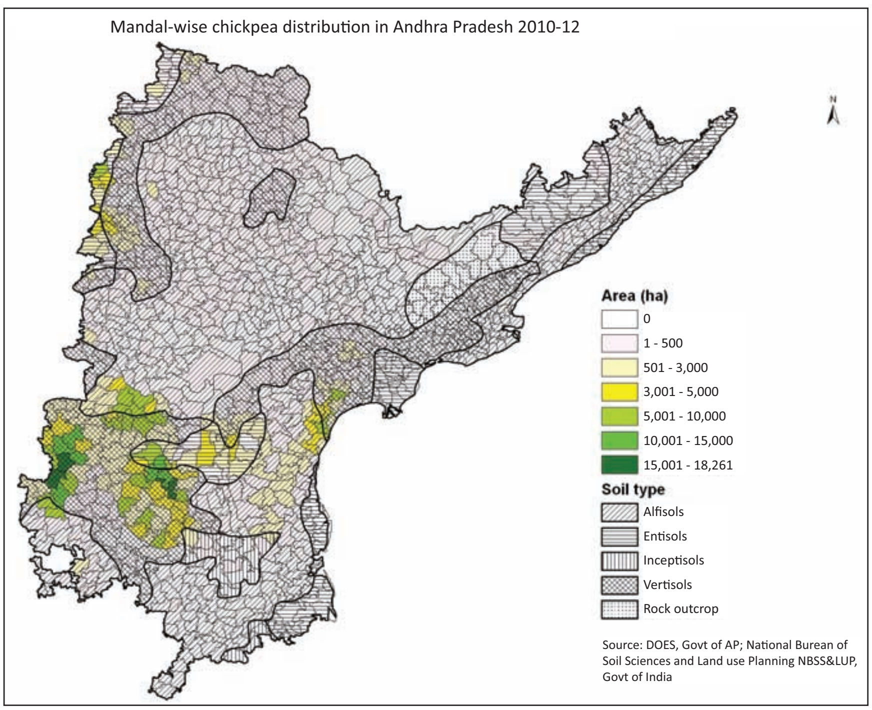

Figure 3.5. Distribution of chickpea area in different soils of Andhra Pradesh.

3.2 Short-duration chickpea research process

The section systematically traces the steps in the research process leading to the release of short-duration (and fusarium wilt resistant) chickpea cultivars in Andhra Pradesh. The evolution of short duration chickpea crop improvement research at ICRISAT in collaboration with NARS partners can be broadly discussed as below:

a) Establishment of germplasm repository

The first systematic international effort to gather chickpea genetic resources of the world was made when ICRISAT was established in India in 1972. The regional and national programs assembled a large number of chickpea lines afterwards. In 1978, the International Bureau of Plant Genetic Resources (IBPGR) designated ICRISAT as the major repository for chickpea germplasm and subsequently a Genetic Resources Unit was established in 1979. Since then ICRISAT, in collaboration with national scientists not only in India but also in Afghanistan, Turkey, Greece, Burma, Ethiopia, Pakistan and Bangladesh, added several accessions to the gene bank. ICRISAT also established research collaboration with International Center for Agricultural Research in the Dry Areas (ICARDA) in 1977 soon after its establishment.

b) Breeding for early sowings in Peninsular India

In general, plant growth and seed yield of chickpea in Peninsular India (Hyderabad, 17°N) is considerably lower than in northern India (Hissar, 29°N). On the other hand, in Peninsular India, the earlier onset of heat and moisture stresses reduces the crop yield to nearly half of the northern India. Chickpea is sown in Peninsular India late in October on land fallowed during the rainy season to conserve moisture. ICRISAT chickpea breeders visualize an opportunity for increasing seed yield by advancing the sowing date from late October to mid-September. Since 1978/79, several germplasm accessions and breeding lines have been evaluated and found superior to the cultivar check 'Annigeri' (ICRISAT 1981). Early sown chickpea lines consistently produced higher yields under both irrigated and dryland conditions. Short-to-medium duration genotypes produced higher yields when sown early. The most promising cultivar identified for September sowing, 'P 1329', also produced a higher yield than the best adapted cultivar when sown at the normal time (ICRISAT 1983). Thus, it was realized that advancing the sowing date indeed increased yield.

c) Development of biotic (Fusarium) resistant cultivars

Fusarium wilt, caused by *Fusarium oxysporum f.sp. ciceri,* is the most important root disease of chickpea in the semi-arid tropics (SAT), where the growing season is dry and warm. Thus, chickpea cultivars targeted for SAT must have resistance to Fusarium wilt. Effective field, greenhouse and laboratory procedures for screening against Fusarium wilt have been developed at ICRISAT (Nene et al. 1981) and more than 160 resistant accessions (150 desi and 10 kabuli) were identified and used in developing wilt resistant cultivars (Haware et al. 1992). Other major disease in SAT is dry root rot. Resistant lines are screened, identified and made available to NARS partners for their breeding program.

d) Breeding for early phenology

This shift in area from cooler, long season (160-170 days) environment to warmer short season (100-110 days) environment has further enhanced the importance and development of short-duration cultivars in Peninsular India. The development of short-duration cultivars in the southern states of India has an advantage in these areas as they can escape end-of-season stresses by maturing early.

Breeding for early maturity has been directed towards the development of extra short-duration varieties to the environments where the growing season is short and the characteristic of drought escape is essential for raising a successful crop. Phenology (time to flowering, podding and maturity) is an important component of crop adaptation in these environments. Crop maturity ranges from 80 to 180 days depending on genotype, soil moisture, time of sowing, latitude and altitude. However, in at least two-thirds of the chickpea growing area, the available crop-growing season is short (90-120 days) due to risk of drought or temperature extremities at the end of the season (pod filling stage of the crop). About 73% of the global chickpea area is in South and Southeast Asia where chickpea is largely grown rainfed in the postrainy season on receding soil moisture and often experiences terminal drought and heat stresses. Early phenology is also needed for promotion of chickpea to rice-fallows and other late sown conditions of South Asia. Hence, the development of early maturing cultivars is one of the major objectives in chickpea breeding programs of ICRISAT, Patancheru, India and in several countries, including India, Myanmar, Bangladesh, Ethiopia, Australia and Canada (Gaur et al. 2008).

Chickpea crop is known to be photo-thermo sensitive and its maturity ranges from 80 to 180 days depending on genotype, soil moisture, time of sowing, latitude and altitude. Lower temperatures, shorter photoperiods and optimal soil moisture, individually or in combination, help in extending growth period, while higher temperatures, longer photoperiods and moisture stress conditions are known to shorten all developmental phases thereby reducing the crop duration (Summerfield et al. 1990). In a study conducted by ICRISAT, the mean number of days to flowering in a set of 25 genotypes were 51 at Patancheru (18°N), 76 at Gwalior (26°N) and 96 at Hissar (29°N) (Kumar and Abbo 2001).

Other research studies conducted by Berger et al. 2004, 2006; Subbarao et al. 1995 also revealed that phenology (flowering time, time of podding and maturity) was considered as one of the key traits for adaptation of chickpea to varied climatic conditions. Flowering time or days to flowering (number of days from sowing to appearance of first flower) can be recorded with high precision and provides fairly good indication of succeeding phenological traits (time of podding and maturity). Thus, most genetic studies in the past have concentrated on flowering time and suggest that it is under control of few genes. Kumar and van Rheenen (2000) reported a major gene (designated *efl-1*) for flowering time in ICCV 2 from its cross with a medium duration cultivar JG 62. Thus, development of short crop duration types through the use of *efl-1* gene has helped reduce damage due to terminal drought. The genetic analysis of different components of crop duration in chickpea reveals earliness to be governed by recessive genes with predominance of additive gene action (Kumar et al. 1999); recurrent selection would be effective in accumulating alleles for earliness. Development of super early lines (ICCV 96029 and ICCV 96030) from crosses between ICCV 2 and ICCV 93929 (which flower in 30 to 32 days at Patancheru) further indicated involvement of more than one gene in controlling flowering time (Kumar and Rao 1996; Kumar and Abbo 2001). ICCV 96029 inherited *efl-1* from ICCV 2 and at least one additional gene affecting early flowering from ICCV 93929. Donors for earliness identified have been used for the development of varieties such as ICCV 2, BG 372 and KPG 59, which have gained acceptance among the farmers of rainfed ecology because of their early maturity combined with other desirable traits. The availability of early varieties has been the main catalyst behind the expansion of chickpea area in South and Central zones. In spite of reduction in duration, the yield potential of these early varieties remains almost unaffected thus improving per day productivity of the crop.

However, the efficient and sustained research collaboration efforts commenced between ICRISAT and national agricultural research system (NARS) partners have led to development of several early maturing kabuli cultivars well adapted to the semi-arid environments, eg, ICCV 2 (ICRISAT 1990), PKV Kabuli 2 or KAK 2 (Zope et al. 2002), JGK 1 (Gaur et al. 2004) and Chefe (Ketema et al. 2005). The development of extra short-duration kabuli variety ICCV 2, which matures in 85-90 days and has resistance to Fusarium wilt, was instrumental in expanding the kabuli chickpea area in lower latitudes, with warmer temperature. Myanmar has also very short-growing season like southern India, now has about 60% of chickpea area under kabuli type. This change was brought by the extra-early cultivar ICCV 2 (released as Yezin 3 in Myanmar), which has witnessed very high rate of adoption and is now occupied nearly 55% of cropped area (Than et al. 2007).

In desi chickpea also, several short-duration cultivars are available which are ideally suited for the short winter season. Some of the most popular cultivars include ICCC 37 and JG 11 (ICCV 93954) in southern India. The variety ICCC 37 was released by the Government of Andhra Pradesh under the name of Kranthi. ICCV 2 and ICCV 10 (kabulis) are preferred in Gujarat because of higher grain price early in the season. ICCV 88202 (Yezin 4) in Myanmar and Mariye in Ethiopia are other popular desi types which have been well adopted in those locations.

The increase in area in southern states is attributed to growth in real prices of chickpea, high productivity levels and growth in limited available moisture conditions which made chickpea competitive among other dry land crops (Gowda et al. 2009). The silent chickpea revolution has taken place in Andhra Pradesh in last two decades through rapid adoption of short-duration chickpea cultivars due to their assured returns and suitability for mechanization making it a higher productivity crop in Andhra Pradesh. It was also estimated that if moisture stress is alleviated, up to a 50% increase in chickpea production could be achieved, with a present value (gross value of extra production) of about USD 900 million (Ryan 1997).

In addition, there is enormous potential (nearly 4 m ha rice fallow) for expanding chickpea area in India by making available cultivars and production technologies suitable to specific niche areas particularly in rice fallow and various late sowing conditions (Kumar et al. 1994 and Subbarao et al. 2001). According to Musa et al. 2001 and Gaur and Gowda 2005, the development of short-duration and super early chickpea lines have better chances of success in rice fallows and in several new farming systems.

Chickpea cultivar releases in Andhra Pradesh: 1978- present

Two types of chickpeas are grown in India based on market demand and farmers' resource availability (see Table 3.3). The desi type is dominant in India (nearly 80%) with the kabuli type occupying the remaining share of the production. Relatively, kabuli types require better soils and supplemental irrigation facilities to attain better productivity. In general, most of the chickpea farmers grow desi types on marginal lands and rainfed conditions (under soil moisture retention). Kabuli types require a little longer duration when compared with desi types. However, the average productivity levels were higher for desi types. Normally, farmers apply better management and inputs to kabuli types. Overall, the kabuli types fetch better prices in the market due to export demand in the international market, although this depends on the overall international market conditions.

Table 3.3. Features of desi vs kabuli chickpea types.		
Characteristics	Desi type	Kabuli type
Area under cultivation	More area	Less area
Color of seed	Yellow to dark brown	White or pale cream
Size of the seed	Small	Large, bold and attractive
Shape of the seed	Irregular and wrinkled	Smooth
Plant structure	Small and bushy	Semi-spreading to semi-erect
Yield potential	Relatively higher than kabuli (2.2 t/ha)	Relatively lower than desi (1.8 t/ha)
Varieties	Jyoti, Annigeri, Kranthi, Bharathi, JG 11, JAKI 9218	Swetha, KAK 2, Vihar
Unit costs of production	Lower	Higher
Unit price per kg	Lower	Higher

A summary list of chickpea varietal releases in Andhra Pradesh is given in Table 3.4. Annigeri was the first improved desi cultivar of chickpea developed through selection from a land race. It was developed by the erstwhile University of Agricultural Sciences (UAS), Bangalore, and released in 1978 and was called 'Annigeri 1'. It was adopted well in parts of Karnataka state initially and entered Andhra Pradesh slowly in early 1990s. Andhra Pradesh had almost negligible cropped area under chickpea cultivation during the early 1990s. However, the extent of adoption of Annigeri became significant by late 1990s in Andhra Pradesh and the cropped area also started expanding. Cultivars such as Jyothi, D 8, ICCC 37, ICCV 10 (Bharathi) and ICCV 2 (Swetha) were released in the 80s and early 90s but were not picked-up well by Andhra Pradesh farmers. Later, improved cultivars JG 11 and JAKI 9218 were identified through multi-location trials and released in 1999 and 2007 respectively. The chickpea farmers in Andhra Pradesh accepted JG 11 very well because of its higher yield, bolder grain size and resistance to Fusarium wilt. It is clearly evident from the table that ICRISAT together with NARS partners played a significant role in the development of short duration improved cultivars in India.

Tables 3.5 and 3.6 feature the prominent characteristics of Annigeri and the other popular varieties, JG 11 (desi) and KAK 2 (kabuli), that became popular and are well liked by Andhra Pradesh farmers. JG 11 is a slightly shorter duration cultivar (5-10 days) than Annigeri. The seeds of Annigeri are smaller in size, wrinkled and have lower seed weight than the new improved cultivar JG 11. Table 3.5 clearly shows the yield advantage of JG 11 over Annigeri (nearly 40%). Apart from this yield margin, JG 11 grain fetches higher price (nearly 10%) than Annigeri. Between the two improved desi cultivars released in late '90s, farmers preferred JG 11 more than JAKI 9218 because of its high yielding and Fusarium wilt-resistant traits, as well as its attractive color, bold and uniform grain size and good market demand.

Table 3.4. Summary of all chickpea releases in Andhra Pradesh.				
Year of release	Cultivar	Desi/ kabuli	Pedigree	Developed/ released by
1978	Annigeri 1	Desi	Selection from local germplasm	Karnataka
1978	Jyothi	Desi	Pure line selection from local	Andhra Pradesh
1982	D 8	Kabuli	Selection from local material	Andhra Pradesh
1984	ICCC 32	Kabuli	L 550 x L 2	ICRISAT/ANGARU
1992	Bharathi (ICCV 10)	Desi	(P 1231 x P 1265)	ICRISAT/NARS
1993	Swetha (ICCV 2)	Kabuli	[(K850 x G45/7) x P458] x L550 Gaumirchil	ICRISAT/ANGARU
1994	Vijay** (Phule G-81-1-1)	Desi	P 127 x Annigeri 1	MPKV, Rahuri
1999	JG 11 (ICCV 93954)	Desi	(Phule G 5 x Narsingpur bold) x (ICCC 37 x 860263-BP-BP-91-BP)	ICRISAT; JNKVV, Sehore and PKV, Akola
2002	JG 130	Desi	[(Phule G 5 x Narsinghpur bold) x JG 740]	JNKVV Sehore
1998	KAK 2 (PKV-Kabuli-2)	Kabuli	ICCV-2 x Surutato-77 x ICC 7344, ICCX-870026-PB-PB-14P-BP-62AK-7AK-BAK	ICRISAT and PDKV, Akola
2002	Vihar/(Phule G-95311)	Kabuli	(ICCC32 X ICCL 8004) X ICC7344)	ICRISAT and MPKV, Rahuri
2001	Kranthi (ICCC 37)	Desi	[(P 481 X JG 62) X P 1630]	ICRISAT/ANGRAU
2005	Digvijay*	Desi	Phule G 91028 x Bheema	MPKV, Rahuri
2006	L Be G-7	Kabuli	ICCV 96329	ICRISAT/ANGRAU
2007	JAKI 9218	Desi	(ICCC37 X GW5/7) X ICCV 107	ICRISAT/NARS
2011	MNK 1	Kabuli	Selection from local germplasms	ICRISAT and ARS Gulbarga
2012	N Be G-3	Desi	Annigeri X ICC 4958	ICRISAT/ANGRAU

** Central release across India

* Released in Maharashtra State, but diffused to other places

Source: Compilation from various CVRC Reports

Table 3.5. Typical characteristic features of Annigeri vs JG 11 (desi types).		
Character	Annigeri	JG 11
Release year	1978	1999
Duration	95-100 days	90-95 days
Plant type	semi-spreading	semi-erect
Seed size	round and medium	very bold
Testa texture	wrinkled	smooth
Seed color	yellowish brown	light brown
Seed weight	16-20gm/100 seeds	22.5 to 24gm/100seeds
Uniformity in crop	not similar	similar
Drought tolerance	low	High
Fusarium wilt resistance	low	high
Resistant to root rot	low	Moderate
Taste	very good	Good
Seed shedding	higher	lower
Price premium	lower	higher
Avegrain yield (kgs/ha)	988-1236	1483-1730

Source: CVRC reports, Seed Division, Govt. of India

Table 3.6. Typical characteristic features of KAK 2 vs Vihar (kabuli types).		
Character	KAK 2	Vihar
Release year	1998	2002
Duration	90-95 days	105 days
Plant type	semi-spreading	semi-erect
Seed size	extra bold	extra bold
Seed color	white color	white color
Seed weight	35-40 gm/100 seeds	34-36 gm/100 seeds
Fusarium wilt resistance	resistant	resistant
Resistant to root rot	moderate	moderate
Price premium	high	high
Avegrain yield (kgs/ha)	1977-2100	1977-2150

Source: CVRC reports, Seed Division, Govt. of India.

Among the kabuli varieties, KAK 2 and Vihar are the most popular short-duration kabuli introductions to southern India. Development of these cultivars created the new opportunity for growing kabuli types in central and southern India. KAK 2 attracted the farmers' attention especially in the eastern part of Andhra Pradesh. In assured rainfall regimes such as in Prakasam district, and pockets of Kurnool and Kadapa districts, farmers have quickly shifted from desi to kabuli cultivation. Vihar, which was released from neighboring Maharashtra state, became popular in the western part of the state. As described in Table 3.6, Vihar matures in a longer period and has slightly higher or equal productivity than KAK 2. Relatively, KAK 2 requires better soils and crop management practices for attaining optimum yields. The detailed information about all major cultivars in Andhra Pradesh (including cultivar name, release year, type, duration, characteristic features like flower color, seed color, seed size, seed weight, plant type, resistance and yield) is given in Appendix 3.

3.3 Research timeline

Table 3.7 summarizes the chronological steps in the research process leading to the release of short-duration and Fusarium wilt resistant cultivars in Andhra Pradesh from late 1980s to till now. The pictorial representation of the complete research process for development of short-duration chickpea cultivars is shown in Figure 3.6.

The research and development effort (and therefore research cost) is reckoned in accordance with the R&D timeline for short-duration chickpea research with identified research products as shown in Figure 3.6. As illustrated, ICRISAT initiated the research for development of short-duration cultivars in 1978. For reference, the full list of ICRISAT based global chickpea releases, in collaboration of respective NARS partners up to 2013, is given in Appendix 4. For Andhra Pradesh in South India, the relevant chickpea releases are summarized in Table 3.8.

The impact assessment analysis in Chapter 7 will refer to these two waves of short-duration improved chickpea releases in India as research products or outputs when it demonstrates the impact pathway which tracks the outputs, outcomes and impacts of short-duration chickpeas in Andhra Pradesh.

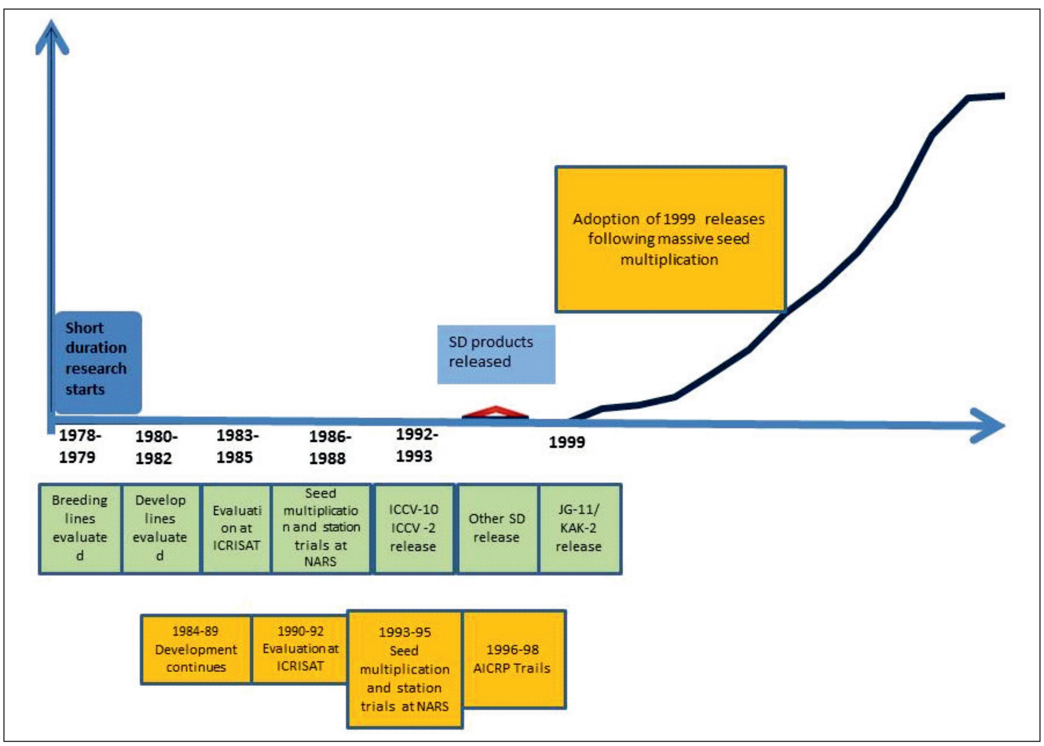

Figure 3.6. Research Process: chickpea short-duration varieties.

Table 3.7. Research process in developing short-duration and Fusarium wilt research conducted by ICRISAT and NARS.

Year	Objective/Activity
1978/79	Breeding lines and accessions evaluated and found superior to cultivar check 'Annigeri' (ICRISAT 1981)
1980/81	Effective field, greenhouse and laboratory procedures for screening against Fusarium wilt developed at ICRISAT (Nene et al. 1981) and original chickpea collection sown in a wilt-sick plot at ICRISAT in Patancheru
1981/82	Development continues; seed collected from resistant plants re-sown in wilt-sick plots for further purification
1983/85	Evaluation at ICRISAT Observed that early sown chickpea lines consistently produced higher yields under both irrigated and dryland conditions. Short-to-medium duration phenotypes produced higher yields when sown early. The most promising cultivar identified for September sowing, P 1329, also produced a higher yield than the best adapted cultivar when sown at the normal time (ICRISAT 1983)
1986/87	On-station trials at NARS location and on-farm adaptation trials
1988	Seed multiplication
1989-91	All India Coordinated Research Project (AICRP) Trials – multi-location screening under the collaborative ICAR/ICRISAT trials
1992	ICCV 10 (Bharati) released (desi type, 110-days duration)
1993	ICCV 2 (Swetha) ICRISAT/NARS release; kabuli 85 days [(K850 x G45/7) x P458] x L550 Gaumirchil; two other varieties Vijay and JAKI 9218 were also released in 1994 and 1997, respectively
Through 90s	More than 160 resistant accessions (150 desi and 10 kabuli) were identified and used in developing wilt resistant cultivars (Haware et al. 1992). Resistant lines are screened, identified and made available to NARS partners for their breeding program Evaluation at ICRISAT station, JG 11, KAK 2 and cohort (1990-92) Multi-location screening for resistance Multi-location trials for short-duration trait On-station and on-farm adaptation trials at NARS location (1993-1994) Seed multiplication (1995) AICRP trials related to JG 11 and KAK 2 (1996-98)
1999	JG 11 and KAK 2 were released in Central Committee for southern India JG 11 is a desi type with 90-110 maturity and KAK 2 is a kabuli with 95-113 days maturity
1999-2001	Seed multiplication of JG 11 and KAK 2 for 2-3 years; Extension after release of JG 11 and KAK 2
2001	ICCV 37 release (desi 90-100 days)
2002	Vihar release (kabuli 105-110 days)
2006	LBeg-7 release (early kabuli)

Table 3.7. Research process in developing short-duration and Fusarium wilt research conducted by ICRISAT and NARS.

Year	Objective/Activity
2012	N Beg-3 release (desi)
2008/13	Further seed multiplication through TL II Project (2008-2013) further boost uptake in AP and Karnataka

During the last five decades in India, chickpea was gradually displaced to marginal rainfed areas during the expansion of rice industry and development of wheat varieties (HYV) during green revolution period. Particularly during the 1975-1990, chickpea has seen tremendous change in terms of area shift of about 3 m ha from northern India (cooler, long-season environments) to southern India (warmer, short-season environments).

Table 3.8. Two waves of short-duration chickpea releases in India (and other countries) in 1993, following the medium-duration chickpea releases before 1993.

Medium-duration releases in India:	
1978	Medium-duration Annegiri 1 released in Karnataka state in India
1978	Medium-duration Jyothi (ICC 4923) released in India
1983	Medium-duration ICCC 4 released in India
1986	Four improved cultivars released in Myanmar (Yezin 1 & 2, Keyhman and Schwe Keyhman)
1985	Medium-duration variety called Mariye (K 850 x F 738 - segregating material supplied by ICRISAT from which selection was made by the national program) was released in Ethiopia
1992	Medium duration ICCV 10 (Bharati) released in 1992 in India. The variety also released as Barichhola 2 in Bangladesh in 1993
First wave of short-duration releases	
1993	Short-duration ICCV 2 (Swetha) released in India. The same variety also released in Sudan in 1998 as Wad Hamid. Later, it also spread to Myanmar and released as Yezin 3 (K) in 2000.
1993	Short-duration Worku Golden (ICCL 82104) was released in Ethiopia
1995	Short-duration Akaki (ICCL 82106) was released in Ethiopia
1998	Short-duration GG 2 released in India in 1998
1998	Short-duration ICCV 88202 (Sona) released in 1998 in Australia
Second wave of short-duration releases:	
1999	Short-duration JG 11 (ICCV 93954) and KAK 2 (ICCV 92311) were released in India
2000	Short-duration Sasho (ICCV 93512 – large seeded kabuli) released in Ethiopia
2000	Short-duration ICCV 88202 was released in Myanmar as Yezin 4
2001	Short-duration ICCC 37 released in India as Kranthi in 2001
2002	Short-duration ICCV 92337 (JGK 1) released in India
2002	Short-duration Vihar (kabuli ICCV 95311) released in India
2006	Short-duration L BeG 7 (ICCV 96329) released for southern India
2007	Short-duration JAKI 9218 (desi ICCV 93952) released for southern India
2011	Short-duration MNK-1 (kabuli) released for southern India
2012	Short-duration N BeG-3 desi cultivar released for Andhra Pradesh

3.4 Research costs

The research cost of short-duration chickpea research at ICRISAT and its partner institutions in NARS was estimated from annual budgets and scientist-years or person-years (PY) allocated to chickpea short-duration research. Historical budget records disaggregated by research program for research conducted at ICRISAT are not available and research investments particularly for chickpea are difficult to reconstruct during the earlier years. Personal communication with ICRISAT Finance Director indicated that as per standard accounting practices, detailed information on programmatic budgets is maintained for only eight years. Thus, for the purpose of this study, expenditure for short-duration chickpea research was estimated with guidance from scientists who were part of ICRISAT's chickpea crop improvement research team during those years, and administrative officers who had some historical recollection of annual budgets. The breakdown of research costs was made on the basis of PYs of scientists and staff of the chickpea research team, standard annual salaries, and the proportion of each scientist's time on development of short-duration chickpeas. Operating costs were estimated from estimated total operating costs for the Grain Legumes Program, which focused on three major research activities during that period. Similar imputations were also made for the NARS counterpart funds.

Low and high budget scenarios may be discussed. The range of budget allocations reflects the variation in estimates made by different staff members. The lower budget scenario is also a way to simulate the effect of marginal budget reductions on the net benefits flowing from the research. The steps described in the summary description of the research process guided the elicitation of the research cost template.

It should be noted that even before the short-duration chickpea research started, essential milestones have already been achieved at ICRISAT on which the above research built on. These include:

- First systematic international effort to gather chickpea genetic resources of the world was made when ICRISAT was established where the regional and national programs assembled a large number of chickpea lines (1972);
- ICRISAT established research collaboration with ICARDA for chickpea crop improvement (1977);
- The International Bureau of Plant Genetic Resources (IBPGR) designated ICRISAT as the major repository for chickpea germplasm (1978);
- Genetic Resources Unit was established and ICRISAT is in collaboration with national scientists in India, Afghanistan, Turkey, Greece, Burma, Ethiopia, Pakistan and Bangladesh, who have added several accessions to gene bank (1979).

Past research investments involving the above establishments provided the foundation for chickpea crop improvement at ICRISAT. Nevertheless, these are considered as sunk costs with respect to the chickpea short-duration chickpea research.

Research and development cost: Start to release

Research and development costs in the development of short-duration chickpeas were attributed to the investments by both ICRISAT and NARS partners involved in the developmental process since 1978. The careful calculations of staff-wise research costs including operating and overheads expenditure for ICRISAT is summarized and detailed in Table 3.9 from 1980-2013. Similarly, NARS partners from four research locations actively participated in the research process (Jabalpur, Nandyal, Dharwad and Rahuri) towards the development of short duration cultivars. The corresponding cost estimates across four locations were presented with detailed break-up in Table 3.10 between 1980 and 2013. The total costs involved for development of short duration cultivars from all the stakeholders (ICRISAT and NARS) including research and dissemination costs are furnished in Table 3.11 over the years. The costs incurred at different time periods were adjusted using appropriate deflator and converted them in to real prices. Overall, the total estimated costs for developing this technology was USD 8.5 million. Around USD 6.8 m (80%) alone was incurred by ICRISAT, while the NARS partners shared the remaining 20% research costs.

Table 3.9. Basis for ICRISAT's annual research costs (USD).

Staff member	% time allocated for short-duration research	In 1980s		In 1990s		In 2000s		In 2010s	
		Cost per year (USD)	Total costs (USD)	Cost per year (USD)	Total costs (USD)	Cost per year (USD)	Total costs (USD)	Cost per year (USD)	Total costs (USD)
1 Principal scientist (Breeding)	0.15	80,000	12,000	95,000	14,250	1,20,000	18,000	1,50,000	22,500
4 National scientists (Breeding)	1.50	8,000	12,000	16,000	24,000	36,000	54,000	50,000	75,000
1 National scientist (Pathology)	0.25	8,000	2,000	16,000	4,000	36,000	9,000	50,000	12,500
6 Research Associates	1.50	2,500	3,750	6,667	10,000	9,333	14,000	13,043	19,565
30 Field Assistants	7.50	1,200	9,000	2,000	15,000	5,500	41,250	10,000	75,000
10 Field Laborers	0.25	750	187.5	1,600	400	4,000	1000	9,000	2,250
Operating expenses			10000		40000		60000		80000
Overheads			7341		19,377		35505		51627
Grand total			56278		127027		232755		338442

Source: ICRISAT Chickpea Crop Improvement Program scientists, personal communication.

Table 3.10. Basis for NARS annual research costs (Rs).

Staff member	% time allocated for short-duration research	In 1980s		In 1990s		In 2000s		In 2010s	
		Cost per year (Rs)	Total costs (Rs)	Cost per year (Rs)	Total costs (Rs)	Cost per year (Rs)	Total costs (Rs)	Cost per year (Rs)	Total costs (Rs)
1 Scientist (Breeding)	0.10	48,000	4,800	1,56,000	15,600	3,00,000	30,000	12,00,000	120,000
1 Scientist (Pathology)	0.10	48,000	4,800	1,56,000	15,600	3,00,000	30,000	12,00,000	120,000
1 Research Associate	0.10	12,000	1,200	48,000	4,800	1,20,000	12,000	3,60,000	36,000
5 Field Laborers	0.50	2,400	1,200	18,000	9,000	72,000	7,200	1,44,000	72,000
Operating expenses	20.0%	50,000	10,000	80,000	16,000	1,20,000	24,000	200,000	40,000
Total per NARS location			22,000		61,000		1,32,000		3,88,000
Grand total*			88,000		2,44,000		5,28,000		15,52,000

* Mainly four NARS research locations were involved in the development process

Source: NARS scientists, personal communication.

Table 3.11. Summary of total research expenditure for development of chickpea short-duration improved cultivars (USD).

		Research costs				Extension	Total costs			
		ICRISAT	NARS			costs	Nominal	Deflator	Deflator	Real
Year	Research activity	USD	Rs	Exchange rate	USD	USD	USD	base=2005	base=2013	USD
1978	Development–Breeding and accessions evaluation for short-duration and Fusarium wilt resistance; sown at wilt sickplots at Patancheru; further purification	56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1979		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1980		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1981		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1982		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1983		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1984	Development continues towards identification of next batch of releases JG 11 and KAK 2	56278	88,000	12	7,395	-	63,673	70.48	0.59	108,411
1985		56278	88,000	12	7,195	-	63,474	69.74	0.58	109,210
1986		56278	88,000	13	6,886	-	63,164	80.22	0.67	94,488
1987		56278	88,000	13	6,785	-	63,063	87.91	0.73	86,087
1988		56278	88,000	15	6,069	-	62,347	93.61	0.78	79,922
1989		56278	88,000	17	5,285	-	61,563	93.05	0.78	79,393
1990	Evaluation of lines at ICRISAT Research station; ICCV 10 released in Andhra Pradesh	127027	244,000	18	13,601	-	140,628	96.60	0.81	174,689
1991		127027	244,000	24	9,971	-	136,998	96.30	0.80	170,722
1992		127027	244,000	31	7,961	-	134,988	97.80	0.81	165,637
1993	ICCV 2 released in Andhra Pradesh; Resistant lines identified and made available to NARS partners for their breeding program	127027	244,000	31	7,781	5,000	139,808	98.34	0.82	170,597
1994	Station trials at NARS locations and seed multiplication	127027	244,000	31	7,771	5,000	139,798	98.58	0.82	170,181
1995		127027	244,000	33	7,294	5,000	139,321	107.75	0.90	155,167

Table 3.11. Summary of total research expenditure for development of chickpea short-duration improved cultivars (USD).

		Research costs				Extension	Total costs			
		ICRISAT	NARS			costs	Nominal	Deflator	Deflator	Real
Year	Research activity	USD	Rs	Exchange rate	USD	USD	USD	base=2005	base=2013	USD
1996	AICRP multi-locational trials conducted at All-India Level	127027	244,000	36	6,873	5,000	138,900	104.41	0.87	159,643
1997		127027	244,000	37	6,566	5,000	138,593	97.89	0.82	169,897
1998		127027	244,000	42	5,800	5,000	137,827	93.08	0.78	177,684
1999	JG 11 and KAK 2 released	127027	244,000	43	5,631	5,000	137,658	91.06	0.76	181,413
2000	Seed multiplication and extension	232755	528000	46	11,559	10,000	254,314	89.33	0.74	341,621
2001	ICCC 37 released	232755	528000	48	11,072	10,000	253,827	84.83	0.71	359,055
2002	Vihar released	232755	528000	48	10,911	10,000	253,666	84.31	0.70	361,051
2003		232755	528000	46	11,491	10,000	254,246	90.19	0.75	338,277
2004		232755	528000	45	11,752	10,000	254,507	97.13	0.81	314,441
2005	Dig Vijay released	232755	528000	44	11,927	10,000	254,682	100.00	0.83	305,618
2006	L Be G-7 released	232755	528000	45	11,661	10,000	254,416	102.17	0.85	298,805
2007	Seed multiplication and extension; Tropical Legumes-II project supported FPVS and seed multiplication	232755	528000	40	13,121	150,000	395,876	108.58	0.90	437,501
2008	TL-II project seed multiplication and distribution in Andhra Pradesh	232755	528000	46	11,501	150,000	394,256	117.09	0.98	404,046
2009		232755	528000	47	11,128	150,000	393,883	109.35	0.91	432,249
2010		338442	1552000	46	34,057	150,000	522,499	112.95	0.94	555,123
2011		338442	1552000	55	28,019	150,000	516,461	122.52	1.02	505,827
2012	N Be G-3 released	338442	1552000	57	27,157	150,000	515,599	119.94	1.00	515,871
2013		338442	1552000	61	25,318	150,000	513,760	120.00	1.00	513,760
Grand total (USD)							7175832			8586850

4. Impact assessment – methodology and data requirements

This section describes the methodology used for welfare estimate calculations and its various sensitivity scenarios. The minimum data requirements for quantifying the impact of any technology are also highlighted and discussed in detail.

4.1 Methodology for estimation of welfare benefits

There has been a long history of using applied welfare economics to measure the impact of and then returns to funds invested in agricultural research. A major review of this literature and excellent summary of the methodology is given in Alston et al. (1995). The majority of applications of this methodology have measured the impacts of research in a particular country where the research was focused and undertaken.

For internationally oriented research organizations, such as the CGIAR system and funding institutions, consideration of the impacts on many countries is important. Indeed it is the international public good nature of these institutions which often provides the basis for their operation. Alston et al, (1995) summarized the methods applicable to internationally focused research; however, there have been further developments since then. These developments have expanded the notion of research applicability between similar production environments or research domains and the associated spillover impacts between countries and regions.

Early work by Edwards and Freebairn (1981, 1982 and 1984) first focused on this issue. They looked at the case of one country undertaking the research and the implications for that country due to spillovers to the rest of the world when the product is traded. They also looked at the importance of spillovers between regions within a country. Extensions to this work to include many countries and regions and model in more detail the applicability and therefore spillovers between them, have been reported by Davis et al. (1987), Davis et al. (1989), Davis (1991), Bantilan and Davis (1991), Fearn and Davis (1991), and Deb and Bantilan (2001). More recently Bantilan et al. (2013) provided a synthesis of these past applications and highlighted how it is being further developed and used at ICRISAT.

In the rest of this section, we briefly highlight the important features of this framework as it will be applied in the analysis in this report.

Bantilan et al. (2013) emphasize that the international research process is a complex activity and that it is important to make sure an impact assessment study considers all aspects to avoid a wide range of potential aggregation and empirical errors. Figure 4.1 is the simplified schematic representation of the research process they used. It illustrates the sub-components of the complex interactions which ultimately lead to impacts and then changed welfare for the community. It highlights the importance of understanding the following aspects:

i. The range of production environments (research domains) that are applicable to chickpeas and especially the one(s) which generated the research focus on short-duration varieties;

ii. The strength of the adaptive research and adoption systems and their implications for quantifying final impacts;

iii. The effects of adoption of the new varieties on farmers' unit cost of production to understand the ultimate shift in the supply in each region/country. It is this shift in the supply which generates welfare changes for both chickpea producers and consumers and ultimately the many groups influenced by the initial chickpea market changes.

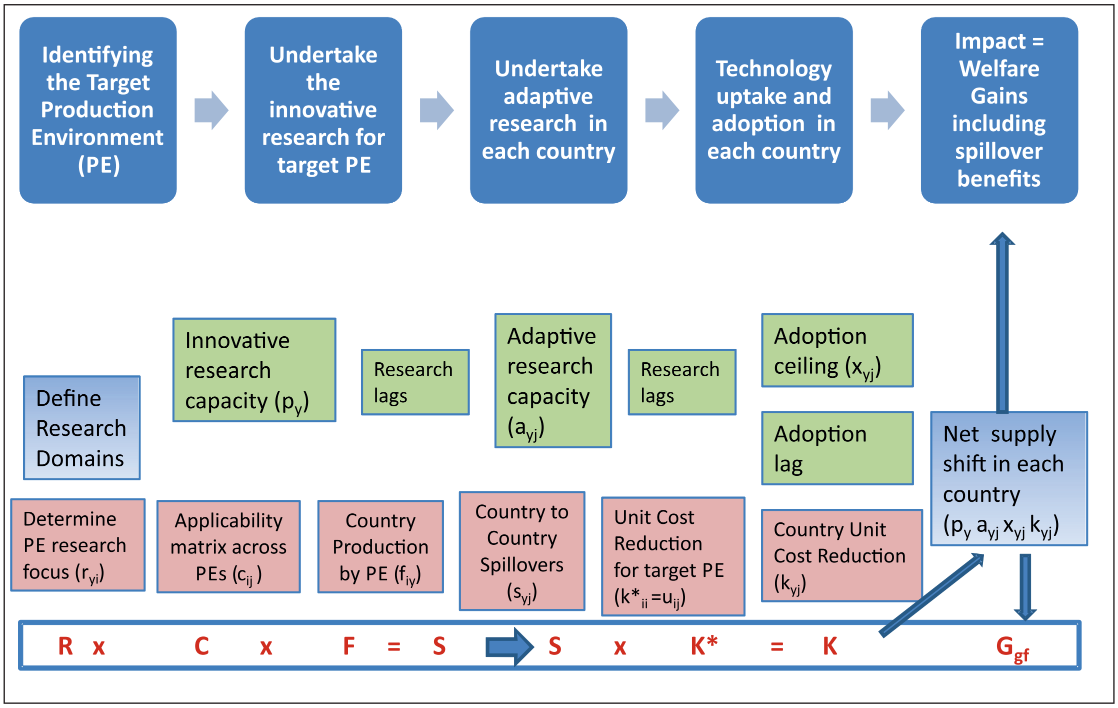

Figure 4.1. Research process and parameters required for welfare impact estimation.

We will not discuss this in detail here; it is too complex. Instead below we briefly discuss three sub-components to highlight the important aspects for this chickpea application. Two are general features of the framework the flow chart summarizes; while the third is an adaptation we found necessary for this specific application. We finish with presentation of the formulae used to estimate the total welfare benefits and their distribution between producer and consumers. This includes a list and brief discussion of the data that is required to effectively quantify these welfare changes.

International trade has been an important aspect of the chickpea environment and has, as was briefly discussed in Chapter 2, facilitated and driven much of the short-duration germplasm technology adoption. Figure 4.2 illustrates how the framework incorporates multi-country traded good interactions. For simplicity only a two-country model with research focused on an issue mostly applicable to country 1 but also applicable to the rest of the world is illustrated. In this study the application actually includes all regions/countries producing and/or consuming chickpeas. As discussed later, to best represent the impact of the short-duration chickpea technology, we found it was important to have over 60 supply/demand situations representing: types of groups of farmers, districts, states, countries and regions.

If research is undertaken on an issue specific to a particular production environment/research domain found mostly in country 1, then the impact of this can be represented as a shift in its chickpea supply. This is shown as a shift from S_{10} to S_{11} in Figure 4.2(a) and is measured as the vertical distance 'k_{11}' which is the unit cost reduction (UCR) due to adoption of the new technology. In country 2 (the rest of the world in this illustration, Figure 4.2(c)) the adoption of the short-duration varieties shifts the aggregate supply from S_{20} to S_{21} measured as a unit cost reduction of 'k_{21}'. In this representation $k_{21}<k_{11}$ or the technology is not as applicable.

The total welfare change due to this research is measured as the sum of the shaded areas in Figure 4.2. There are four areas, one in each country for the change in producer's welfare (called producer surplus) and the other in each country for the change in consumer welfare (consumer surplus). It can be seen that depending on the nature of the supply and demand in each country and the applicability, adaptation, adoption and other dimensions highlighted by Figure 4.1, there are many possible patterns of the distribution of the welfare changes. These shares of benefits are also determined by the world price impacts of the adoption of the research which shifts the supplies and associated excess demand and supply in the world market, illustrated in Figure 4.2(b).

In addition to taking account of spillovers between countries and the world price effects, it is important to ensure the level of disaggregation of the analysis is sufficient to accurately represent the impact of the new technology.

Figure 4.3 can be used to illustrate the importance of this issue. If we take country 1 in Figure 4.2(a) and disaggregate it into three separate groups of producers, Figure 4.3(d) then becomes the aggregated supply corresponding to Figure 4.2(a), the demand is left out for simplicity. The three disaggregated supplies might represent a range of alternative production situations. Here, we identify different types of adopters. The first type, shown in Figure 4.3(c), might be the farmers to whom the short-duration varieties are applicable. Before the availability of the new short-duration varieties, they produced the old short-duration variety or varieties. Adopting the new varieties shifts their supply by reducing their unit cost of production. Figures 4.3(a) and (b) might represent a range of other producer situations. One possibility is each represents the long and medium duration producers. For them, the short-duration varieties do not provide a yield and thereby any cost advantage so they do not adopt them. Their supplies do not change or shift.

Alternatively one of these groups could be producers of the old varieties who do not adopt the new ones because they face several of the many factors which could constrain their adoption. For example, the seed production and distribution systems may not support them.

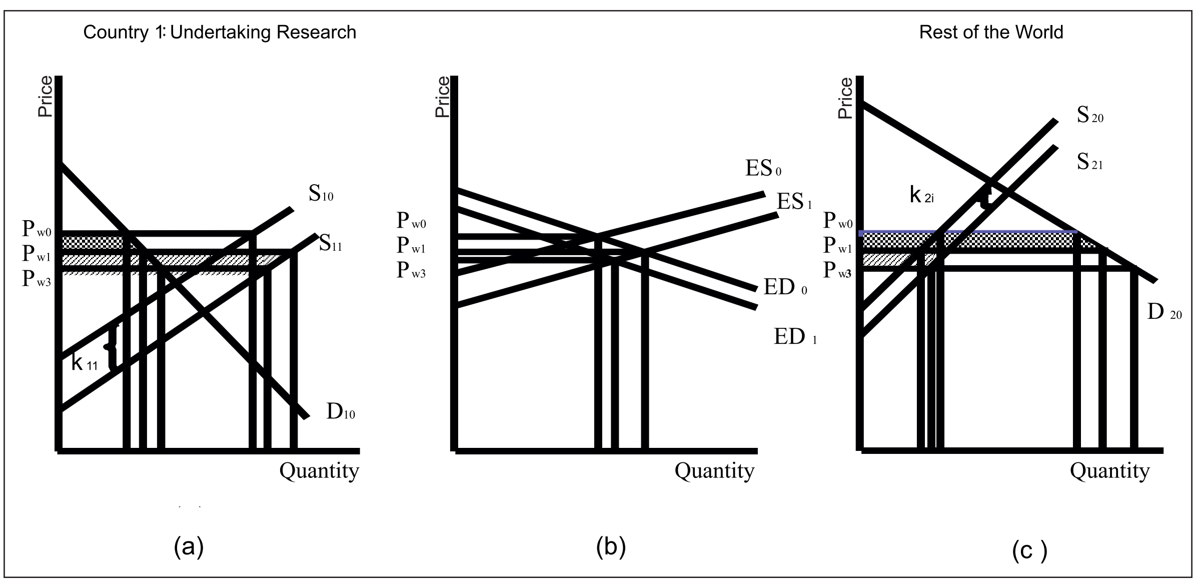

Figure 4.2. Two-country/region traded good research impact framework.

Regardless of the reason for the non-adoption or applicability of the new technology, the impact on welfare changes is demonstrated. The aggregated supply, Figure 4.3(d), interfaces with the rest of the world supply and demand as in Figure 4.2; there are potentially other adopting producers in other regions or countries and disaggregated demands, which may result in price changes. At a disaggregated level, we now see that producers in Figure 4.3(a) and (b) experience a welfare loss due to research, the pink shaded areas. Producers in Figure 4.3(c), in Figure 4.3(d) still have welfare improvements. This mixture of impacts is hidden by the aggregation in Figure 4.2; there producers as an aggregated group have a net welfare gain – the welfare gains of adopters exceed the losses of the non-adopters.

In addition to masking the range of important implications of research impacts, if the aggregated representation of supply, Figure 4.2(a), is used, then there is a significant chance that an empirical error will be made in estimating the welfare changes. The blue shaded area of welfare change in Figure 4.3(d) has a much different shape to the equivalent parallelogram plus triangle in Figure 4.2(a). While it is possible that with careful detailed understanding of the disaggregated environment and careful mathematical manipulation of the supply-shift parameter, errors will not be made, the chance of successfully achieving this is low. If this detailed understanding is developed, then a disaggregated model might as well be used since it facilitates incorporation of each component of the story in its appropriate form rather than developing an additional set of complex mathematical manipulations to achieve this. In the process, many important aspects of the underlying impact story will be lost[1].

During early discussions with research groups, focus-group meetings and on the basis of the survey results, it became clear that the new short-duration varieties were so profitable to farmers, especially combined with the changed market environment, that many farmers who had not previously produced chickpeas were switching to chickpeas from other crops. As discussed in Chapter 2, the additional area planted to chickpea has been substantial. To facilitate better understanding of these changes and impacts, farmers growing chickpeas were separated into five groups in the survey data analysis. These were:

- Non-adopters, NA – farmers who continue to grow the old varieties
- Adopters, A1 – farmers replacing existing varieties with the new short-duration varieties

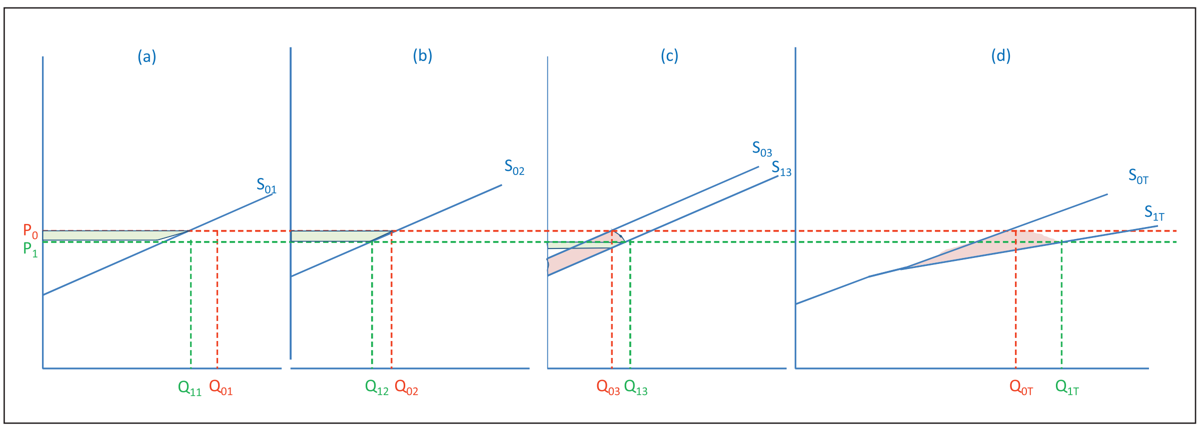

Figure 4.3. Disaggregation based on types of adopters.

[1] Davis (1994) discusses this disaggregation issue in more detail.

- Adopters, A2 – farmers (A1) substituting the new varieties for other crops grown on part of the farm
- Adopters, A3 – farmers (A1) acquiring, leasing or purchasing, additional land to grow the new varieties
- Switchers, SW - farmers who have not grown chickpeas before and replace other crops.

After analyzing the survey information from this perspective, it was decided that the impact assessment analysis should disaggregate the potential short-duration chickpea producing areas, especially Andhra Pradesh into at least three groups of farmers: NA; A1 and A2+A3+SW.

It was therefore important to consider whether the underlying supply theory included in the methodological framework outlined above accommodates the third group of switchers – those expanding the area planted to chickpeas – and if so whether there are any guidelines to ensure effective empirical application. It is worth briefly discussing each of the three groups to keep them all in perspective.

Figure 4.4 considers the non-adopters, NA. Before research, their supply of chickpeas is S_0 and at the market determined price P_0 they supply $Q_{0,NA}$. Notice, we have drawn the supply with a kink at the point of minimum total average cost (TAC) (= marginal cost (MC)). For existing producers, the kink point is usually not important; so in many studies, for simplicity, the supply is drawn as a straight sloping line to the axis. Figures 4.2 and 4.3 used this convention. Note also for simplicity, we have not drawn the rest of the disaggregated market and aggregated diagram which determines the equilibrium price, P_0.

After research, these farmers do not adopt the new varieties so their supply remains the same, shown as S_0&S_1. However, since other farmers do adopt, after research the aggregate supply and demand situation results in a price fall to P_1, causing the non-adopters to reduce their output to $Q_{1,NA}$. As was discussed in relation to Figure 4.3, non-adopting farmers now loose due to the impact of research – their price is lower. In some cases, eventually the kink point may be important if

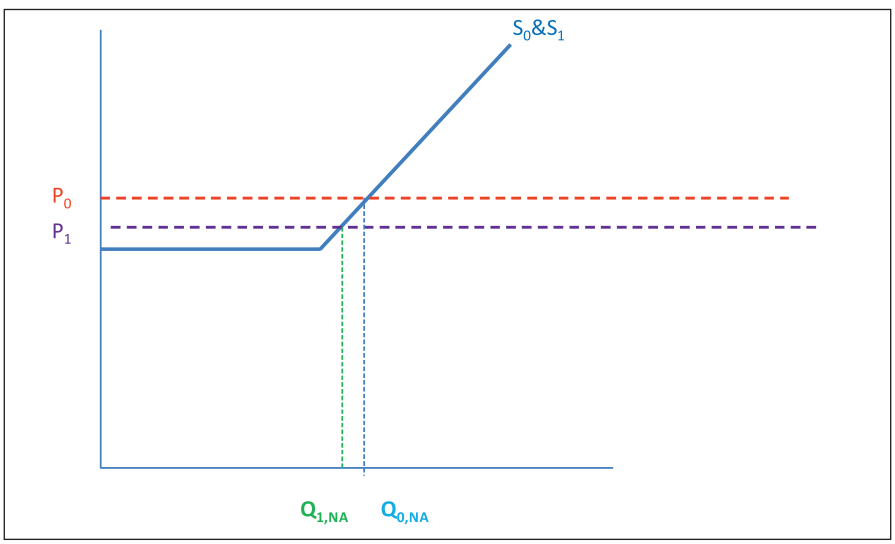

Figure 4.4. Representation of non-adopters: before & after research.

new improved varieties continue to be developed and released and the non-adopters continue not to adopt them; eventually the after research equilibrium price may fall below their kink price point. These non-adopter farmers will switch to other crops or move out of farming and sell/lease their land to, probably, adopters. However, the quantum of chickpea produced by non-adopters (NA group) is minimal. So, there are no changes anticipated in surplus for these non-adopters and therefore the current estimates are reasonable.

Figure 4.5 considers the adopters, A1. This is equivalent to the illustration in Figure 4.3(c) but with a kinked supply. Adopting the new varieties reduces costs by 'k' and shifts their combined supplies from S_0 to S_1. In the aggregated market, the price again falls from P_0 to P_1. The after research production level of adopters is increased to $Q_{1,A1}$. This is the usual situation when a new variety is just an improvement over an existing one; but does not facilitate expansion to production environment(s) where the crop was previously not very suitable. There will be some increase in the area but these are the usual price responses not due to farmers operating at kink points. Having said this though, unless the full cost situation is known for each case, it is not possible to tell when kink points or switchers-substitution may be stirred into action. As a rule this should always be checked for; however, without detailed surveys (like the one undertaken for this study) it may not be easy to know when a new technology creates this situation.

The important group for this study is the farmers who have expanded production onto additional land not previously used for chickpeas, that is, A2, A3 and SW farmers. Although it can be useful to consider each of these three groups separately, the diagrammatical representation is basically the same. For all of them the new varieties mean that the farm gate market price is now higher than their 'with technology' kink point in their supply. Figure 4.6 depicts their 'with' and 'without' research supply situation.

Before the release of the new varieties, it was not profitable to grow chickpeas on these areas of land – they had better, more profitable alternatives. The price for chickpeas, $P_{0,}$ was below their minimum total average cost of production, TAC_{min} (=MC), including the opportunity cost of producing

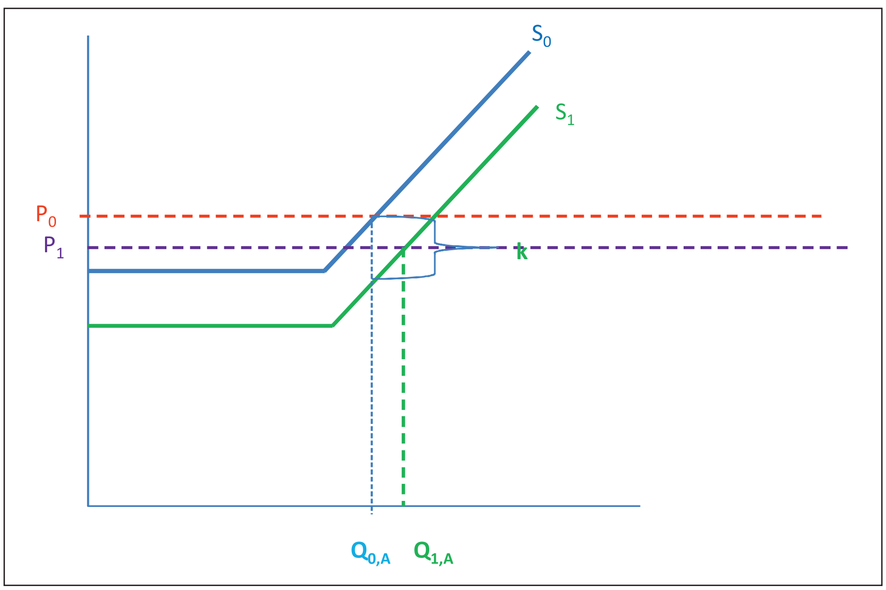

Figure 4.5. Representation of adopters: before & after research.

the more profitable crops. Their before research production was $Q_{0,SW}$, that is, zero. After the release of the new varieties, it is now profitable to grow chickpeas and many do so. The supply shifts by k_s (which is the reduction in the unit cost of production, UCR) and production increases to $Q_{1,SW}$ at the new after research equilibrium price, P_1.

The crucial issue for this group of farmers is: what is the appropriate measure of welfare gains due to the farmers switching land to chickpea production; and how then do we estimate this, given we are dealing with farmers and their production at the kink or switching point of their supply functions.

In the usual case of the adopter, the welfare gains for the new technology are estimated as the area between the 'without research' supply and the 'with research' supply bounded by a line between the intersections with the price line before and after the research is adopted. The supply shift measured by the UCR of k_s and the before research production are usually important determinants of this area. The 'without research supply' for the switchers is not observable because there is no production before adoption of the technology. While it would be possible to estimate the total average cost for the switchers for the old varieties and therefore k_s, the information would not come from actual production information – rather from hypothetical farm cost analyses.

However, the welfare change for adoption by switcher farmers can be shown to be the area under the original price line P_0 and above the with research switcher supply, S_1. This is found by estimating the area of a rectangle plus a small triangle. The rectangle area is found by finding the difference between the before research farm gate price and the after research TAC_{min} or unit cost (UC). The production is the level of output at the kink point of the supply. However, Figure 4.7 shows that the welfare change inducing 'supply shift' due to switchers is $k<k_s$. If the UCR k_s is used, the welfare change will be overestimated by the area between the without research price line and the TAC_{min}. How large this error might be depends on how much higher than P_0 the without research cost is. The alternative though is to use the without research price and the unit cost after research to give k.

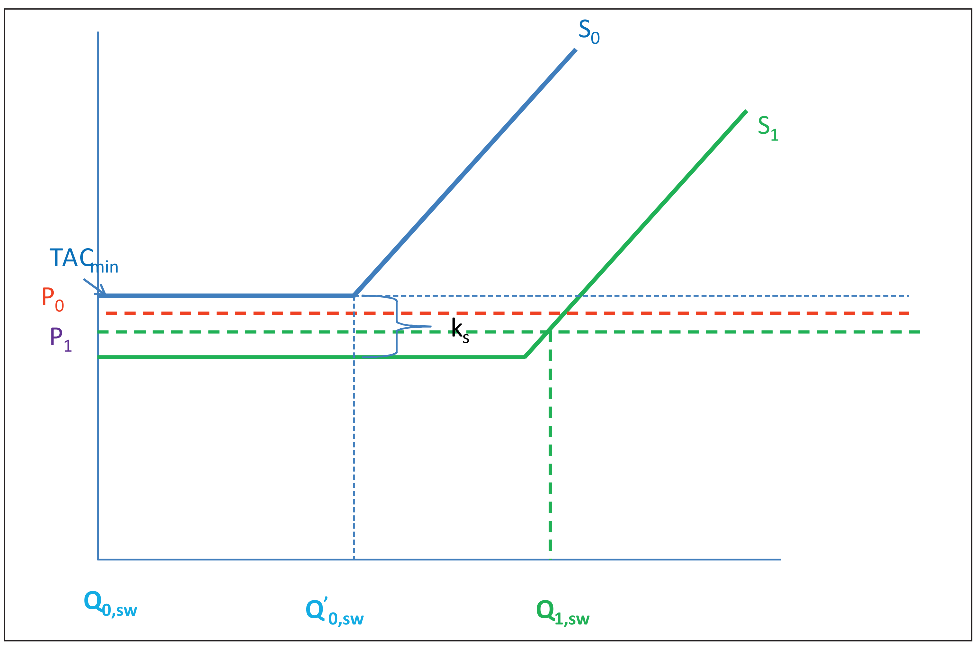

Figure 4.6. Representation of switchers: before and after research production levels.

The other important issue is that the price response via standard supply elasticities does not handle the extreme switcher situation. The switcher response (and also the existing producers who expand their areas significantly) are not responding to a price change rather a substantial reduction in the unit cost of production and therefore increase in profitability (which in fact will be at a lower price).

Some caution is required with this recommendation. True farm gate prices are often difficult to obtain. To be sure they are accurate, farmer surveys are required. As a general rule using commodity prices to derive supply shifts (UCRs) should be avoided. Price series are difficult to find which do not have many off-farm service cost included. They can cause very large overestimates of welfare gains. If there is lack of confidence in the available farm gate prices, then an alternative approximation for the switcher UCR is:

$$UCR_s = UCR_a - (UC'_a - UC'_s). \qquad (4.1)$$

Where:

UCR_s is the unit cost reduction (supply shift) of switchers

UCR_a is the unit cost reduction (supply shift) of adopters in the same region

UC'_a is the unit cost of production for the adopters with the new technology

UC'_s is the unit cost of production for the switchers with the new technology

This in effect means using the without research counterfactual adopter UC for the switcher counterfactual – equation 4.1 reduces to this if it is expanded out. In equilibrium this should equal P_0.

Since both measures can contain significant errors if the underlying information is not accurate, judgment is required by those collecting the data regarding which method has the most reliable underlying data.

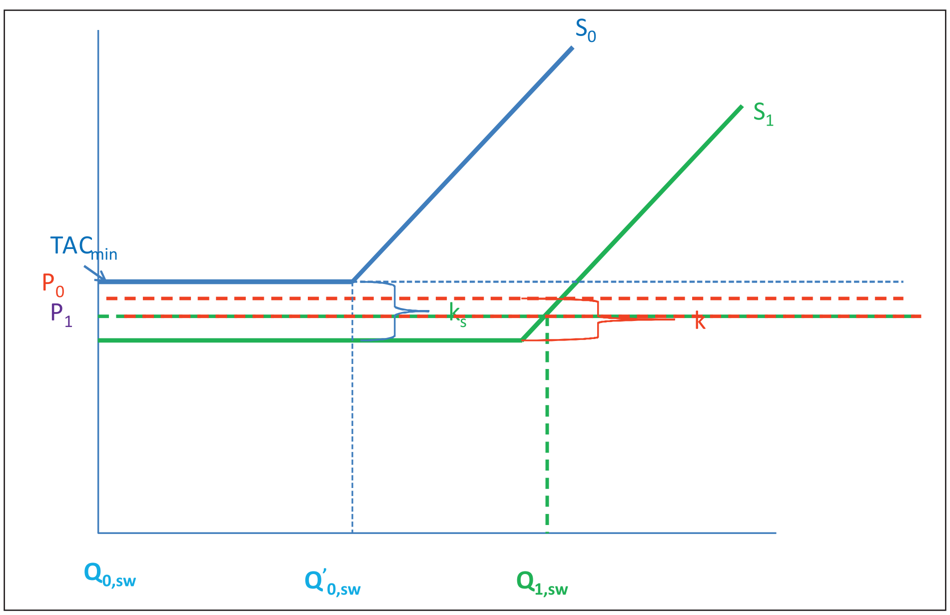

Figure 4.7. Illustration of the Potential Error if use full UCR for Switchers.

Figure 4.8 is used to demonstrate diagrammatically what the above suggestion would involve. The constructed supply, S_0^*, is the without research or what is usually called the counterfactual supply. The vertical distance between this and the with research supply, $S_{1,}$ is the counterfactual UCR, k. To use the usual formulae for estimation of the welfare changes due to research, the additional information required is the 'without research' production. Since this was zero, again we need to estimate this counterfactual production. It is the production consistent with the kink point in both supplies. The appropriate estimate of the counterfactual production is the area switcher's plant to the new variety multiplied by the new variety yield. This information should be available from detailed surveys; if this is not possible, then a good approximation would be $Q_{1,sw}$ although this could involve some possible over estimation.

In summary, to accommodate disaggregation of a country, state or region to include switchers as a separate group of farmers requires:

i. Estimates of the shares of farmers and there production in the switcher group and therefore also in the other disaggregated groups, in this case non-adopters and existing producer adopters. This information is required each year from the start of adoption through to the full adoption year.

ii. Construction of a switcher counterfactual supply for each year to match the adoption levels. This is best estimated using the yield and estimates of area changed to chickpeas. If not readily available, then an estimate of the actual production by switchers for each year would be an acceptable approximation, $Q_{1,sw}$.

iii. Estimation of the supply shift or UCR for switchers. This is best estimated as the without research equilibrium price less the unit cost of the new variety for the switchers, estimated from a switcher cost analysis. If the analyst does not have confidence that the farm gate price is an accurate estimate of the price for each farmer group, then an alternative approximation for k is to use the adopter UCR and the adopter 'with research' unit cost compared to the switcher unit cost: see the discussion around equation 4.1 for this process.

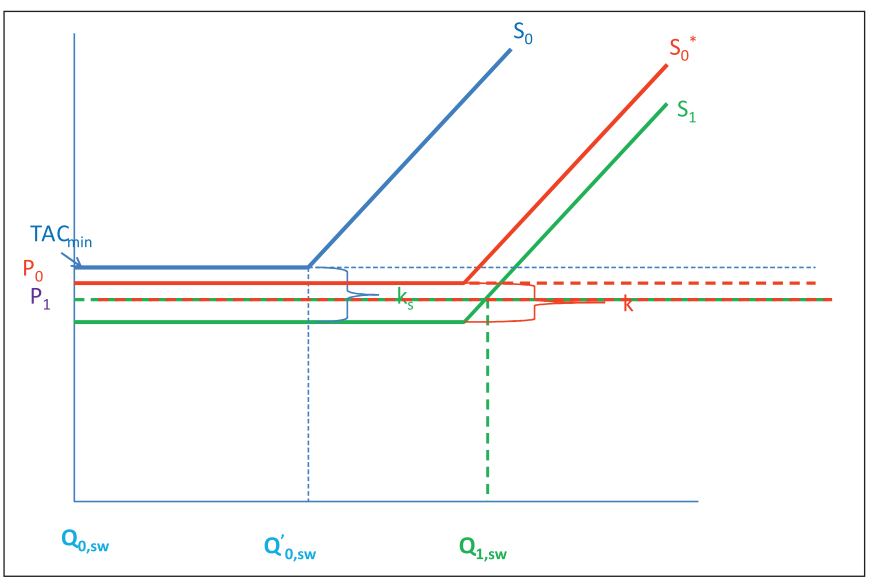

Figure 4.8. Estimation of the correct welfare gains with adjusted UCR and supply.

Formulae for estimation of welfare changes

The welfare impacts consistent with the above framework can be estimated using formulae adapted from Bantilan et al. (2013; pp 34-36). This set of formulae includes all of the parameters identified in Figure 4.1. Some are only important for ex-ante impact assessment analysis. They have been left in the formulae for this ex-post analysis and are included in the spread sheet model developed for the analysis. This is because it is important in the early stages of an impact assessment study to specifically consider all parameters and systematically give them a value after considering them carefully. In some case, this may mean a value which makes that parameter redundant. For example in most ex-post studies, the probability of innovative research success, p_{yt}, will be set at 1.[2]

The individual benefits for each farmer group, district, state or country 'f' from the research on short-duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{gf})] = \sum_{t=1}^{T}\sum_{f=1}^{n}\frac{p_{gt}\,a_{gft}\,x_{gft}\,k_{gft}}{(1+d)^{t}}Q_{sft}$$
$$+\sum_{t=1}^{T}\frac{p_{gt}(Q_{dft}-Q_{sft})\sum_{i=1}^{n}\beta_{i}\,a_{git}\,x_{git}\,k_{git}}{(1+d)^{t}\sum_{i=1}^{n}(\beta_{i}+b_{i})}$$
$$+\sum_{t=1}^{T}\frac{p_{gt}\,b_{f}\,(\sum_{i=1}^{n}\beta_{i}\,a_{git}\,x_{git}\,k_{git})^{2}}{2(1+d)^{t}(\sum_{i=1}^{n}(\beta_{i}+b_{i}))^{2}}$$
$$+\sum_{t=1}^{T}\frac{p_{gt}\,\beta_{f}}{2(1+d)^{t}}[a_{gft}\,x_{gft}\,k_{gft}-\frac{\sum_{i=1}^{n}\beta_{i}\,a_{git}\,x_{git}\,k_{git}}{\sum_{i=1}^{n}(\beta_{i}+b_{i})}]^{2} \quad (4.3)$$

Consumer benefits for each farmer group, district, state or country 'f' from the research on short-duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{cgf})] = \sum_{t=1}^{T}\frac{p_{gt}\,Q_{dft}\sum_{i=1}^{n}\beta_{i}\,a_{git}\,x_{git}\,k_{git}}{(1+d)^{t}\sum_{i=1}^{n}(\beta_{i}+b_{i})}$$
$$+\sum_{t=1}^{T}\frac{p_{gt}\,b_{f}\,(\sum_{i=1}^{n}\beta_{i}\,a_{git}\,x_{git}\,k_{git})^{2}}{2(1+d)^{t}[\sum_{i=1}^{n}(\beta_{i}+b_{i})]^{2}} \quad (4.4)$$

[2] Bantilan et al., (forthcoming) provide more details on the importance of maintaining this linkage between ex- ante and ex- post impact assessments.

Producer benefits for each farmer group, district, state or country 'f' from the research on short-duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{pgf})] = \sum_{t=1}^{T} \frac{p_{gt} Q_{sft}}{(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\beta_i + b_i)}]$$

$$+ \sum_{t=1}^{T} \frac{p_{gt} \beta_f}{2(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\beta_i + b_i)}]^2 \qquad (4.5)$$

where:

P_{yt} is the probability of success of the innovative short-duration chickpea research undertaken by ICRISAT and its partners 'y' in year 't' ($0 \leq p_{yt} \leq 1$). As was noted above this value was set to 1 in the analysis since the original research was successful[3];

a_{yft} is the probability of success of adaptive research undertaken in each district, state, country or region 'f' for the short-duration varieties developed by ICRISAT and its partners 'y' in year 't' ($0 \leq a_{yft} \leq 1$). Again for most groups of farmers, districts, states and countries this parameter was set to 1. However, there are several of these where this adaptive research did not occur so the parameter was set to zero[3].

x_{yft} is the expected level of adoption of the new short-duration chickpea varieties developed by ICRISAT and its partners 'y' by producers in each district, state, country or region 'f' (f = 1 … N) in year 't' ($0 \leq x_{yft} \leq 1$). This parameter can change each year and will. Underlying specification of this parameter is an understanding of the complex interactions of various research and adoption lags plus an assessment of when adoption reaches its ceiling level.

k_{yft} is the unit cost reduction (UCR) resulting from adoption of the short-duration chickpea varieties developed by ICRISAT and its partners, 'y', in each district, state, country or region 'f' (f = 1 … N) in year 't'.

d is the social discount rate in real terms.

Q_{sft} is the quantity of chickpeas produced in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual production level.

Q_{dit} is the quantity of the chickpeas consumed in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual consumption level.

b_f and b_i are the slope parameters (dQ/dP) of the demand function in district, state, country or region 'f' or 'i'. Note that $b_i = e_{di} [Q_{dit}/P_{it}]$, where e_{di} is the elasticity of demand for the commodity in district, state, country or region 'i' evaluated at the original equilibrium prices and quantities, Q_{dit} and P_{dit}. Note because negative signs are included in the demand specification the absolute value for these parameters are entered in the formulae.

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[3] Bantilan et al. (forthcoming) provide complete set of equations and other details.

$ß_f$ and $ß_i$	are the slope parameters (dQ/dP) of the supply function in district, state, country or region 'f' or 'i'. Also note, $ß_i = e_{si} [Q_{sit}/P_{it}]$ where e_{si} is the elasticity of supply.
N	is the total number of district, state, country or region producing and consuming chickpeas in the world.

Figure 4.1 includes a complex schematic for identification and modeling of research domains, research applicability and spillovers between all producers and consumers of chickpeas. This is achieved through adjusting the unit cost reduction, k, parameter. This was not formally used to calculate the UCR for each farmer grouping, district, state, country and region in the current study. However, the modeling process was used as a testing template for each UCR that was estimated for each group.

A brief summary of the underlying relationship is:

$$K = K^*S \quad (4.6)$$

Where:

K	is a matrix of monetary direct and indirect spillover unit cost reductions. K is an N x N matrix where N is the number of countries/regions in the world. Each component of K, that is, k_{yjt}, is then the unit cost reduction in country/region 'j' resulting from research undertaken in country/region 'y'. This is what is used in equations 4.3 to 4.5.
K*	is a diagonal matrix of potential cost reductions for each country. k^*_{yy} is the potential cost reduction in country 'y' where the (innovative) research is undertaken, with all $k^*_{yj} = 0$.
S	is a matrix of research spillover indexes. In most cases it is expected that $0<s_{yj}<1$; although this is not a necessary condition of the framework.

$$S = R\,C\,F \quad (4.7)$$

Where:

S	is the same N x N spillover index matrix as in equation (4.6).
R	is an N x m matrix of potential research focus parameters; 'm' is the number of production environments (research domains) relevant to production of the commodity and for a particular type of research problem being considered. Research can be focused on one production environment or a mix of them in different proportions by assigning an index r_{yi} $(0 \le r_{yi} \le 1)$ and $\sum_{i=1}^{m} r_{yi} = 1$ for country 'y'.
C	is an m x m matrix of the research applicability's between production environments for each commodity, c_{ij}.
F	is an m x N matrix of the shares of commodity production (production proportions) in each production environment for each country, f_{iy}. Again $\sum_{i=1}^{m} f_{iy} = 1$ for country 'y'.

4.2 Summary of data requirements

The minimum data requirements for the analysis using the framework outline in this section is embedded in the above discussion. It is worth briefly summarizing these here with some brief comments. In the application section, these will be revised in detail and the important sources and adjustments to this data to support the analysis will be discussed.

The important sets of data are:

Level of aggregation and disaggregation

As the discussion earlier in this section highlighted, tailoring the level of disaggregation to ensure the important impacts are not aggregated into a general story is a very important consideration. As will be discussed in the analysis section, the final choice required many iterations and considerable scrutiny of the survey results. The final disaggregation has enabled several important stories to be told and lessons learnt.

Production

A substantial set of historical production, area planted and yield information were assembled and used to guide the disaggregation strategy; the same data set was also crucial in understanding the complex story of this technology adoption and impact. As will be discussed in more detail based on the above considerations, the choice of the counterfactual production data was a major activity, with the final choice requiring many interactions. This is to be expected since these data are very crucial to the size of the final welfare benefits estimates.

Consumption

Data set on consumption of agricultural commodities is difficult to assemble; especially as a disaggregated level within a country is required. Once the base line for the production was chosen, the consumption to match this was assembled.

Farm gate price

The detailed farm level survey and focus group discussions provided a good basis for developing a reliable set of farm gate prices. International prices were assembled from national sources. This data set is often difficult to obtain effectively. As long as the correct form of the framework is used and minimal use is made of prices to indirectly estimating some of the other critical parameters, this data is not as important as some of the others in terms of a source of large fluctuations in final welfare estimates.

Research lag (years)

This very important parameter was estimated via detailed discussions with research groups and careful reviewing of many documents and varietal release information. Details were provided in Chapter 3 and are discussed again in the later chapters.

Adoption parameters

Adoption lag; Years from research start to start of adoption; Years from release of the new technology to start of adoption; Years from research start to ceiling level of adoption; and Maximum adoption. This set of parameters is crucial and has a major impact on the level of benefits. It is also important in drawing implications about the impact of the technology. Information was enhanced by the extensive survey. The basis for estimation of the parameters is discussed in detail in Chapter 6 and also in 3.

Unit cost reduction

Estimation of this crucial parameter was both intensive and extensive activity. Full details are discussed in the survey and analytical sections.

Elasticity of supply and demand

These were taken from ICRISAT's extensive set of past studies.

Discount rate

The standard accepted discount rate of 5% was used.

Research Cost

These are discussed in detail in Chapter 3.

Final benefit/cost analysis

The above set of 120 plus welfare change estimates and the stream of research and extension activity costs from Chapter 3 are included in a financial analysis to give summary financial measures. These are:

Net Present Value (NPV)

Benefit/Cost Ratio (B/C)

Internal Rate of Return (IRR)

Final words of caution

The extensive body of applied welfare analysis literature assures us that the estimates of total welfare changes provided by application of this framework are very good approximations of what will occur. However, it cautions us about the final accuracy of the estimates for the distribution of these welfare changes. The economic framework is partial equilibrium so all the economic interactions are only the first round impacts on the world chickpea markets. General equilibrium considerations tell us that the second and subsequent round interactions will dissipate these first round welfare distributions much more widely throughout the local and then world economies. The efficiencies and even inefficiencies (through the many government interventions) of all other markets in agriculture and the rest of the world economy will influence the final distribution of these welfare changes. These are very complex so the ultimate distributional impacts will often surprise many! However, the important point is that applied welfare economics theory tells us that as long as those applying the framework have a good understanding of this theory when making judgments about data selection and interpretation, then the total welfare changes are a very good approximation of what is achieved.

In addition to these two estimation issues, there is the further issue of which Q_0,t should be used. That is, which years 'without research' production should be used? This is complex and needs to be considered with a clear picture of the way the adoption parameter is used in the estimation of the welfare gains.

This raises a crucial issue of making sure that the counterfactual situation is well defined. At the year of the ceiling adoption the Q_0 is the production without the research in year t-1. It is crucial therefore to use the estimate of this production as the level for all years before that.

Overall, many lessons learnt while undertaking this comprehensive impact study in Andhra Pradesh. They are as follows:

1. It emphasizes the real worry about using the percentage change in yield as the estimate of the horizontal supply shift. This misses the whole discussion of important aspects of production theory as well as the real risk that the implicit vertical shift can be unrealistically very large.

2. There were several arguments over parallel, pivotal, divergent etc. supply curve shifts in the IA literature. This study has provided a solution to this issue with incorporation of 'kinks in supply functions'. By going back to TAC and MC curves for different production systems/ potential adopter groups, they provide a schema for capturing differential responses to new technology options that in principle provide a way of aggregating them into an implicit "after adoption" aggregate supply curve. This then avoids having to assume a certain type of aggregate supply shift as is the current practice. There are a number of other advantages in doing this, not the least is the added scope for linking ex-post and subsequent ex-ante impact assessment that is based in the first instance on production systems/research domains/recommendation domains and the exploitation of revealed spillover potentials among them."

3. This study also highlights the conclusion that each impact assessment study is very different. An assessment specific spread sheet analysis is nearly always required and therefore the real concern with software such as DREAM. These black boxes do not make the analyst keep asking the crucial questions. In fact they facilitate aggregating these questions away.

4. The study also highlight the importance of dis-aggregation of all key parameters so that the precision of estimation of welfare benefits will increase. Empirically, the study has proved that UCRs across different may not be same. The welfare benefits are underestimated when used the aggregated UCRs across PEs.

5. It highlights the concern about the trend to focus attention on environmental and social impacts – the fundamental production impacts are still rarely well understood let alone effectively estimated. It also highlights why we shudder when the 'evaluation society' impact studies start using qualitative subjective measure of impacts.

5. Survey details

This section describes the collection of primary data using a sample survey to enable an in-depth analysis of the adoption process. The survey was designed to ensure that it provided information for the welfare analysis.

5.1 Sampling framework and randomization procedure

Development of an appropriate robust sampling strategy is a critical important step in ensuring a truly representative sample for this study. There were several rounds of discussions with crop improvement scientists and SPIA team members (including Doug Gollin and Tim Kelley) and suggested experts on this issue. For example, Tavneet Suri, a sampling expert from the Massachusetts Institute of Technology (MIT) gave valuable advice during the development of the sampling frame. Guidelines developed by Tom Walker and Abdoulaye Adam (2012) for the Diffusion and Impact of Improved Varieties in Africa project (DIIVA Project) was also referred to during the sampling process. The methodology as described below ensured a representative sample at each stage from primary level (mandal), secondary level (village) and tertiary level (household).

The critical issues carefully considered during the sampling process are as follows:

1. The primary sampling unit is determined at the mandal (sub-district) level, considering the results of the analysis of the available data on area, production and yield.

2. There are around 1120 mandals existing in Andhra Pradesh from 23 districts. There are 329 mandals growing chickpea, but only 61 with area larger than 3000 hectares[4] (based on 2009-11 secondary data – Table 5.1). The spatial distribution of area grown to chickpea is shown in Figure 5.1 below. Given limitation of budget and time, a sample of 30 mandals was randomly selected proportional to size (ie, chickpea production area) out of the 61 mandals using a randomization procedure (see Annexure 9).

3. At the secondary sampling stage, ie, the village, similar proportional to size sampling is applied. Three randomly selected villages from each mandal were drawn. Hence, a total of 90 villages across the chickpea growing areas were selected randomly in Andhra Pradesh.

4. A random sample of nine chickpea growing farm-households was identified irrespective of land holding size criterion[5]. A post-stratification sample scheme will be implemented during the analysis.

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4. In Andhra Pradesh, on an average, each mandal consists of 30-40 villages. Undertaking a primary survey was considered not cost effective if a particular village is not growing a minimum area of 100 ha under chickpea. Thus, the survey determine the cost effective cut-off point of 3000 ha (30 X 100 ha) per mandal.

5. The land revenue records available with Village Development Officer (VDO) were used in the process of random selection of chickpea and non-chickpea growers. Based on VLS data in Andhra Pradesh, the proportion of landless lessees is very minimal (less than 2%). Thus, we considered the use of land revenue records as a good basis for objective sample selection with minimal sampling bias.

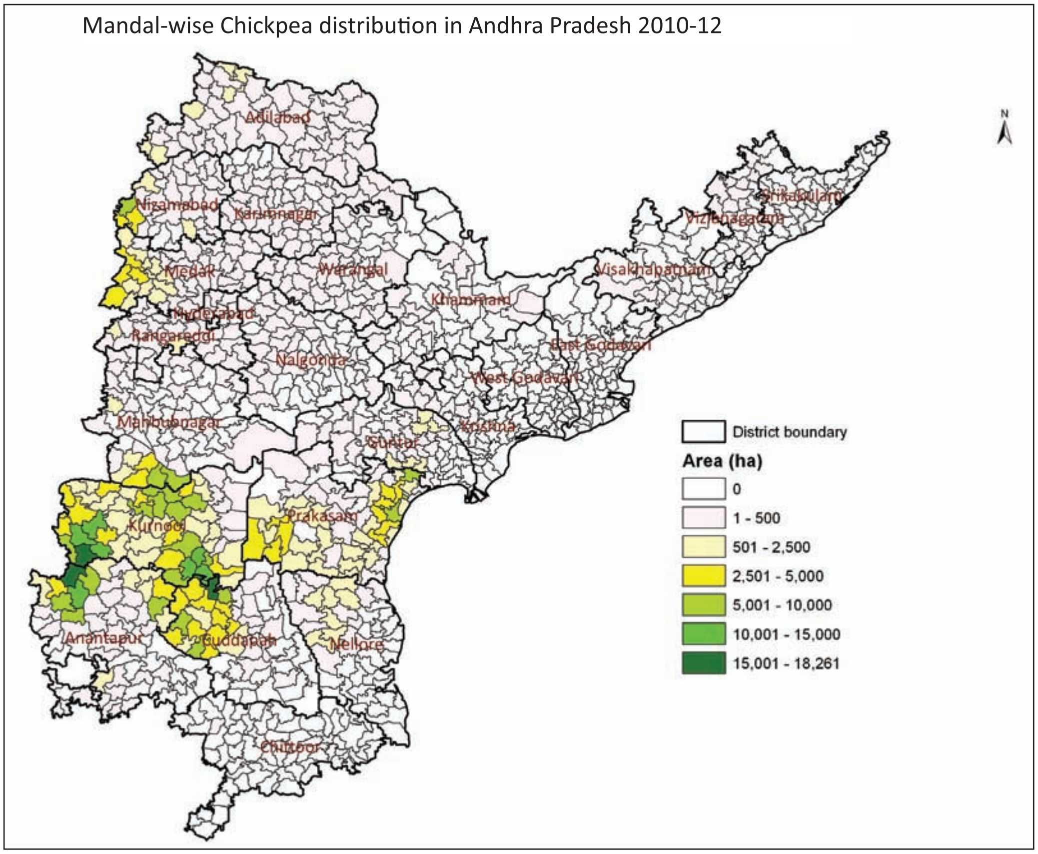

Figure 5.1. Mandal-wise spatial distribution of area grown to chickpea in AP, 2010-12.

Overall, three villages were randomly chosen from each selected mandal in the study. Thus, a total of 90 villages from 30 mandals were formally surveyed in seven districts (out of nine) of Andhra Pradesh (See Table 5.2 and Figure 5.1).

Table 5.1. List of mandals with chickpea area greater than 3000 ha.

District	Chickpea growing mandals	No. of mandals with >3000 ha	Total chickpea cropped area	Area coverage of mandals with >3000 ha	% covered
Anantapur	42	7	81362	64717	79.5
Kurnool	53	23	209255	172291	82.3
Kadapa	30	12	79942	68043	85.1
Nellore	18	0	10728	0	0.0
Prakasam	50	10	84004	45853	54.6
Guntur	30	0	10514	0	0.0
Mahabubnagar	31	3	27035	18438	68.2
Medak	45	3	31014	11721	37.8
Nizamabad	30	3	20705	13788	66.6
Total	329	61	554559	394851	71.2

Table 5.2. Primary, secondary and tertiary samples based on the sampling frame constructed.				
District	No. of mandals growing chickpea	Mandals with chickpea area > 3000 ha	No. of mandals selected for the study	No. of villages covered in the study
Kurnool	53	23	13	39
Prakasam	50	10	4	12
Anantapur	42	7	5	15
Kadapa	30	12	5	15
Medak	45	3	1	3
Nizamabad	30	3	1	3
Mahabubnagar	31	3	1	3
Andhra Pradesh	281	61	30	90

Time series data on area, production and yield were obtained from FAOSTAT and relevant Government of India and State of Andhra Pradesh offices. State (sub-national) and district data were collected for examining the spatial distribution of crop production across all of India. More detailed sub-district (mandal) distribution available for the whole state of Andhra Pradesh was used as basis for constructing the primary level sampling frame for the study. The systematic collection of available census village/household data followed to construct the secondary and tertiary sampling frame for the study. For example, it was most useful to be guided by the spatial GIS map drawn using the mandal level data available.

Table 5.3. Final sample of mandals for the chickpea survey.					
Serial no.	District	Mandal	Serial no.	District	Mandal
1	Anantapur	Kanekal	16	Kurnool	Dornipadu
2	Anantapur	Vidapanakal	17	Kurnool	Sanjamala
3	Anantapur	Tadpatri	18	Kurnool	Uyyalawada
4	Anantapur	Uravakonda	19	Kadapa	Mylavaram
5	Anantapur	Beluguppa	20	Kadapa	Peddamudium
6	Kurnool	Gudur	21	Kadapa	Rajupalem
7	Kurnool	Kurnool	22	Kadapa	Simhadripuram
8	Kurnool	Midthur	23	Kadapa	Veerapunayunipalle
9	Kurnool	Adoni	24	Prakasam	Parchur
10	Kurnool	Alur	25	Prakasam	Janakavarampanguluru
11	Kurnool	Aspari	26	Prakasam	Naguluppalapadu
12	Kurnool	Banaganapalle	27	Prakasam	Ongole
13	Kurnool	Chippagiri	28	Mahabubnagar	Manopad
14	Kurnool	Maddikera (East)	29	Medak	Manoor
15	Kurnool	Koilkuntla	30	Nizamabad	Madnoor

Out of the 281 chickpea growing mandals in seven districts, mandals with chickpea area more than 3000 ha was initially considered for the study (ie, nearly 61 mandals). The details on the sampling scheme (specifying the number of sample mandals, sample villages and sample households) are presented in Table 5.2. A sample of nine chickpea growers was randomly selected and interviewed with a structured questionnaire. The above formal surveys were complemented by a series of focus-group discussions (FGDs) which were conducted in each study village to capture both the quantitative and qualitative impacts of chickpea technology on farmers. The study collected information that pertained to the 2011-12 cropping season. Overall, a total of 810 households was covered from 90 villages and 30 mandals in seven districts of Andhra Pradesh representing more than 71% of the chickpea area in the state. The details of final sample mandals selected for study are summarized in Table 5.3.

5.2 Development of appropriate counter-factual scenarios

It is almost a decade after the introduction of the improved chickpea technology in Andhra Pradesh state and rapid diffusion of these cultivars has already taken place. Initial estimates obtained from crop improvement experts indicate that more than 90% of cropped area is now under improved chickpea cultivars in AP; and identification of the remaining 10% area would be very challenging. It is also noted that there has been no socio-economic baseline survey conducted during last decade which may also serve as benchmark for establishing the counterfactual on a "before and after" impact analysis.

Given the current situation in chickpea production in Andhra Pradesh, two counter-factual scenarios are required for analysis. The first is comparison of farm-households (HH) growing old and new improved chickpea cultivars; and the second involves the comparison of farm-households growing chickpea and non-chickpea crops.

The above situations were considered while developing and finalizing the sampling strategy. An additional sub-sample of three non-chickpea growing farm households was included in the sample in addition to the nine chickpea farm-households in each village. Thus, 33.3% representation of non-chickpea growers would be a good representation for establishing the second counter-factual in the study. Overall, the study is covering 1080 respondent farm-households from 90 villages (nine chickpea HH and three non-chickpea HH).

5.3 Development of survey instruments and protocol

Adoption and impact survey instruments

The development of household and village questionnaires harnessed ICRISAT's vast experience in conducting the ICRISAT 'Village Level Studies (VLS)' as well as its strong competence in implementing adoption and impact studies. The aim is to keep the household survey instrument simple and restricted to about 15 pages. The budget and time constraints were also binding and are seriously considered in the sample survey design and implementation. Refer to Appendix 7 and 8 which present the final household and village questionnaires used in the survey.

The survey instruments were developed, pretested, modified and refined through several iterations with group of chickpea experts from Andhra Pradesh and sample farmers. The household and village questionnaires were finalized after extensive on-site pre-testing in Prakasam district which involved the scientists (economists and breeders together) and field investigators commencing the 2012 postrainy cropping season. It was also pre-test in five villages of Kurnool district with the help of NARS partners from Nandyal station. Keeping in view some of the nagging issues involving the emerging chickpea crop intensification in southern India and in particular in the state of Andhra Pradesh and ICRISAT's interest in sustainable agricultural production in the SAT region where this crop is primarily grown, some additional variables were incorporated to enhance the questionnaire. The modules were refined after incorporating the feedback from farmers and considering the quality of information provided by them. The research/survey team spent more than one week on pre-testing and an additional week on finalization of survey instruments.

Varietal identification protocol

ICRISAT undertook the study with a component to develop and test a varietal identification protocol for chickpea. The protocol was designed and validated through field testing and in collaboration with breeders to increase the accuracy of varietal adoption estimates. This varietal identification protocol especially developed for the chickpea adoption and impact study in Andhra Pradesh evolved through close discussions with experts on chickpea crop improvement both from ICRISAT and the NARS partners including Acharya N G Ranga Agricultural University (ANGRAU) and other experts and stakeholders.

A simple 10-question survey (protocol) was used to administer to chickpea growing households in chickpea growing districts in Andhra Pradesh, India. The simple protocol relies on identifying chickpea improved varieties based on phenotypic characteristics, ie, a combination of distinguishing characteristics of chickpea varieties – related to maturity, growth habit, flower color, pod shape, etc. – to identify traditional and specific improved varieties. The protocol survey was tested on a pilot scale among rural households with the aid of photographs to assist respondents in identifying the variety of chickpea.

The protocol was modified and refined through several iterations which considered as well the sample protocols developed for other crops shared by SPIA. Appendix 6 includes the details of this finalized protocol. Results show a high rate of correspondence between expert classifications and the protocol's classifications indicating the awareness of farmers on the improved varieties in contrast to the earlier dominating varieties which have been adopted for more than 30 years in AP.

The varietal identification protocol was piloted in Prakasam district. This pre-testing was conducted during the 2nd week of November 2012 and the feedback from farmers was useful in validating and finalizing the protocol developed. The chickpea farmers in Andhra Pradesh were observed to have very good awareness about improved cultivars and its plant types. Nearly 80-90% of farmers were able to clearly indicate the cultivar name and its features to the survey team. At the same time, the research/survey team also confirmed that there were no traces of local races and inter-species cultivars.

5.4 Focus group meetings (FGM) to enhance survey information

Discussions with chickpea field experts were undertaken during the survey design and testing. Reconnaissance surveys undertaken during the rabi chickpea growing season from Nov 2012 to January 2013 brought out observations which provided a basis for systematic analysis of spatial data. Important observations were drawn from the consistent responses from FGM farmers and stakeholders which indicated that: "By and large, almost 85% of the farmers in the 90 study villages are chickpea growers', with plot areas ranging from 1 to 100 acres. The remaining farmers who are not growing chickpea in these villages indicated that they are not growing chickpea because the soils were not suitable (eg, red, sandy and chalky soils) or having access to irrigation facilities." This perspective from the FGMs presented as one empirical question which may be tested or verified from the surveys.

5.5 Disaggregation into 5 types of adoptors

Also based on focus group discussions with chickpea field experts (which were repeated even after the surveys were finished), the analysis of impact from the adoption of short-duration chickpeas cultivars were realized to be even more involved. As well as farmers who previously did not grow chickpeas expanding their area, even those who previously grew chickpeas have not only adopted the new varieties but also expanded their area planted. From the survey information it seems that this expansion has been in two ways: (i) by substituting or switching from other crops and (ii) purchasing or leasing additional land which previously did not have chickpeas planted on it.

If this is the current situation in Andhra Pradesh, then it was decided to classify (or disaggregate) farmers into well-defined categories of five groups, as discussed in the methodology sections in Chapter 4. This led to further disaggregation by types of adopters, and then to the need to better understand the production theory underlying costs and then supply shifts.

- Non-adopters, NA – farmers who continue to grow the old varieties
- Adopters, A1 – replacing existing varieties with the new short-duration varieties
- Adopters, A2 – substituting the new varieties for other crops grow on part of the farm
- Adopters, A3 – acquiring additional land to grow the new varieties
- Switchers, SW – farmers who have not grown chickpeas before and replace other crops.

6. Key findings from primary household surveys

This chapter presents the results from primary household adoption surveys and data analysis. This includes the socio-economic profile of chickpea traditional and non-traditional growers in Andhra Pradesh, their land holding status, cropping pattern details and asset values, uptake and diffusion process of chickpea improved cultivars. It also reports on key variables that are essential in assessing the benefits accruing from the adoption of the improved short-duration varieties. This includes costs and returns in crops cultivation, average household incomes and expenditures, unit-cost reductions due to adoption of new technology and ultimately the welfare benefits. This comprehensive analysis of the farm level survey data addresses farm level responses with respect to diffusion, adoption, dis-adoption, input use and crop management.

The details obtained through focus-group meetings are summarized in Appendix 5. These responses are primarily used to validate or cross-check the household level information collected in that particular village. The feedback helps in assessing the village information regarding extent of adoption of different cultivars, their average yields, price trends and various reasons for their preferences etc. Sometimes, they serve as a backup sources of information, particularly if the primary data has any descriptencies or outlayers.

6.1 Socio-economic profile: Occupational pattern, landholding status, cropping pattern and others

Chickpea is a relatively new postrainy season crop sown by farmers in Andhra Pradesh. This is consistent with the available district level data which indicated that chickpea was not even classified as a minor crop in Andhra Pradesh until 1985. The farm survey average figures in Table 6.1 show that the representative sample of farmers growing chickpea have been farming for more than two decades but most farmers (except in Medak district) have only started growing chickpeas during the last 10 years. While Medak's farmers are seen on average to have been growing chickpea the longest (more than 16 years now), farmers from Kurnool, Anantapur and Prakasam were the first switchers from non-chickpea to chickpea crop about 10 years ago. The newcomers to chickpea production come from Nizamabad, Kadapa and Mahabubnagar. This information re-confirms that Medak farmers are the traditional growers of chickpea in Andhra Pradesh. Most of the sample farmers are male headed (99.2%) with an average age of 48 years. The education levels (schooling years completed) were observed to be higher in Kadapa district followed by Anantapur, Prakasam and Kurnool. The average size of the family including children is around 5.00. The sample households in Medak possess the highest size of 5.85 while the lowest was observed in Prakasam (3.97). Overall, the contribution of males is slightly higher (53%) than females in the family size. Three out of five members in an average family is engaged with the family's agricultural work. The proportion of male contribution to family work is pre-dominant (54 %) in all the sample districts in the study. 1.36 members in an average family also participate in outside labor markets.

Table 6.1. General characteristics of sample households									
Item/ Districts	Unit	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Years of farming	Years	22.5	23.4	21.2	24.3	25.3	21.25	24.3	23.1
Years of CP farming	Years	9.5	10.9	8.9	11.1	16.9	7.4	9.2	10.4
Household head	Male	106	348	134	135	27	27	27	804
	Female	2	3	1	0	0	0	0	6
Average age	Years	50.3	47.4	47.3	48.8	50.2	49.6	50.3	48.3
Education (years completed)	Years	6	6	8	7	5	5	5	6
Average size of family*	No.	3.97	5.21	4.75	5.20	5.85	5.59	5.29	5.00
No. of male*	No.	2.12	2.77	2.54	2.74	3.26	2.89	2.63	2.65
No. of female*	No.	1.85	2.44	2.21	2.46	2.59	2.70	2.66	2.35
No. of family labour (no.)*	Male	1.42	1.66	1.46	1.66	2.18	1.88	1.70	1.62
	Female	1.24	1.43	1.40	1.38	1.41	1.55	1.37	1.39
	Total	2.66	3.09	2.86	3.04	3.59	3.43	3.07	3.01
Participation in labor market (no.)*	Male	0.45	0.93	0.43	0.70	0.96	0.70	1.22	0.75
	Female	0.38	0.75	0.37	0.54	0.77	0.66	1.00	0.61
	Total	0.84	1.68	0.80	1.24	1.73	1.36	2.22	1.36

* including children in the family

Occupational patterns of sample farmers

The details about the occupational structure of the sample households are presented in Table 6.2. Overall, 97% of the sample households are dependent on agriculture as a major occupation for their livelihood. Around 2% of the total sample stated that non-farm labor was their primary source of income. Very few sample households are either regular salaried job-holders or dependent on livestock for their main source of income. This pattern is clearly evident across all the sample districts in the study. However, all the farmers are dependent on a wide range of secondary sources of income. The prominent secondary occupation (nearly 42%) observed in the sample was livestock rearing. It was followed by non-farm labor (21.5%), income from rents (8%) and other skilled jobs (3.5%). About 17% of the sample households reported that they didn't have any secondary sources of income. More or less equal occupational structures have been observed across the sample.

The details about castes categories of the sample households are also discussed in Table 6.2. Nearly 51% of the survey households belonged to advanced castes (Open Category) while 42% hailed from backward castes (BC). Scheduled Castes (SC) and Scheduled Tribes (ST) together accounted for 7% in the whole sample. However, the share of scheduled castes is much higher than scheduled tribes. The distribution of the sample to different caste categories varies from district to district.

Table 6.2. Occupational details of sample farmers.									
Item	Description	PRM N=108	KUR N=351	KAD N=135	ANA N=135	MED N=27	NIZ N=27	MAH N=27	Total N=810
Main occupation	1. Agriculture	103	335	134	134	27	27	26	786
	2. Non-Farm Labor	2	11	1	0	0	0	1	15
	3. Employee	1	0	0	1	0	0	0	2
	4. Livestock	0	2	0	0	0	0	0	2
	5. Others	2	3	0	0	0	0	0	5
Secondary occupation	1. Agriculture	5	16	1	1	0	0	0	23
	2. Agril. Labor	3	19	2	3	0	0	0	27
	3. Non-Farm Labor	18	85	18	26	9	6	12	174
	4. Livestock	47	132	62	67	7	15	9	339
	5. Skilled Labor	3	18	0	5	2	0	1	29
	6. Income from rentals	3	26	16	12	2	2	1	62
	7. Others	0	5	3	5	0	3	3	19
	8. None	29	50	33	16	7	1	1	137
Caste category	BC	23	174	34	61	11	23	17	343
	OC	72	151	101	71	9	3	6	413
	SC	12	25	0	3	7	1	4	52
	ST	1	1	0	0	0	0	0	2

Land holding particulars of sample households

The particulars about landholdings held by the farmers surveyed are summarized in Table 6.3. The average for owned land in the pooled sample was 5.83 ha. However, the mean for owned land is much larger in the case of Anantapur followed by Kurnool and Kadapa districts. The smallest mean was observed in Prakasam. Nearly 88% of owned land across the entire sample is rainfed, while the remaining 12% has access to irrigation facilities. The share of irrigated area in the total own-land holdings of the respective districts was much higher in case of Medak (30%) and Nizamabad (21%) districts. Own-land holdings that are rainfed are much higher in Anantapur followed by Kurnool and Kadapa districts.

Leasing-in land from outside land market is a peculiar characteristic in chickpea cultivation in Andhra Pradesh. The average leased-in land for the pooled sample farmers was 1.86 ha, which is almost 25% of the total landholding operated by the whole sample. The average leased-in land per household was the highest in Prakasam district (2.76 ha) followed by Kurnool (2.05 ha), Mahabubnagar (1.81 ha), Anantapur (1.62 ha) and Kadapa (1.35 ha) districts. Nearly 50% of the total operated landholding in Prakasam was contributed by leased land. Similarly, these shares were almost 25% in case of Kurnool and Mahabubnagar districts. More than 91% of the leased-in land is under rainfed cultivation while remaining area enjoyed some irrigation facilities. Around 2% of the pooled total operated land holding is either leased-out or kept permanently fallow. Some of the reasons for permanent fallow lands may be high soil salinity, poor drainage facilities and poor fertility. On the whole, the average operated land holding of the total sample was 7.57 ha which is quite high in rainfed cultivation. The average operated holdings were the highest for Kurnool (8.54 ha) followed by Anantapur (8.28 ha), Kadapa (7.39 ha) and Mahabubnagar (6.58 ha) districts. Due to more leasing-in land in Prakasam, the average operated landholding size became relatively higher (5.60 ha) than Medak (4.28 ha) and Nizamabad (4.18 ha). Quick adaptation to mechanized operations as well as leasing-in new land for upscaling chickpea cultivation are the peculiar features of the chickpea revolution in Andhra Pradesh.

Table 6.3. Average landholding sizes of sample (ha per household).

Item	Type	PRM N=108	KUR N=351	KAD N=135	ANA N=135	MED N=27	NIZ N=27	MAH N=27	Total N=810
Total own landholding	Irrigated	0.22	0.93	0.72	0.46	1.20	0.67	0.72	0.72
	Rainfed	2.72	5.66	5.44	6.48	2.80	2.53	4.05	5.11
	Total	2.94	6.59	6.16	6.94	4.00	3.20	4.77	5.83
Leased-in land	Irrigated	0.04	0.32	0.04	0.02	0.13	0.00	0.12	0.16
	Rainfed	2.72	1.73	1.31	1.60	0.35	0.98	1.69	1.70
	Total	2.76	2.05	1.35	1.62	0.49	0.98	1.81	1.86
Leased-out and permanently fallow	Irrigated	0.01	0.02	0.06	0.02	0.21	0.00	0.00	0.03
	Rainfed	0.09	0.07	0.07	0.26	0.00	0.00	0.00	0.10
	Total	0.11	0.09	0.13	0.28	0.21	0.00	0.00	0.13
Operated landholding	Irrigated	0.26	1.23	0.71	0.46	1.13	0.67	0.84	0.85
	Rainfed	5.35	7.32	6.68	7.82	3.15	3.51	5.74	6.72
	Total	5.60	8.54	7.39	8.28	4.28	4.18	6.58	7.57

Cropping systems and cropping patterns of households

Understanding the existing cropping systems and various cropping patterns of the sample households is critical before assessing the adoption of improved chickpea cultivars in sample districts. Details about major chickpea cropping systems in the sample districts are presented in Table 6.4. The most adopted chickpea cropping system across all sample districts was 'Fallow–chickpea'. Farmers keep their land fallow during the kharif (rainy season) and subsequently take up chickpea cultivation during rabi (postrainy) season. Chickpea farmers open up land furrows with tractors/bullocks soon after receiving the rains during rainy season (ie, in July onwards). This practice allows the black cotton soil (vertisols) to retain rain water to the best extent possible. The retained residual moisture will allow growing chickpea crop during late September or October in a normal year. This is the most predominant practice in black soils for conserving soil moisture. In few places such as Medak and Nizamabad where the quantum of rainfall is much higher (around 900 mm), farmers grow short-duration (65-70 days) pulse crops, preferring either green gram or black gram crops. In some parts of Nizamabad district, where irrigation facilities are available, farmers are growing soybean in the rainy season followed by chickpea in the postrainy season. In case of Anantapur, farmers with alternative irrigation sources prefer to grow groundnut during kharif followed by chickpea in rabi. However, chickpea farmers tend to prefer to keep their land fallow during rainy season for obtaining more productivity per unit during the postrainy season and also to sustain soil fertility for longer periods.

Table 6.4. Major chickpea cropping systems in study districts (ha).							
Cropping system	ANA	KAD	KUR	MAH	MED	NIZ	PRM
Black gram – Chickpea	-	-	-	-	4.25	13.56	-
Fallow – Chickpea	776.19	701.82	1865.43	107.09	39.27	3.64	398.89
Green gram – Chickpea	-	-	-	-	4.05	21.66	-
Groundnut – Chickpea	6.80	-	-	-	-	-	-
Jute – Chickpea	-	-	-	-	-	-	0.40
Onion – Chickpea	-	-	1.21	-	-	-	-
Paddy – Chickpea	-	-	1.62	-	-	-	-
Pigeonpea – Chickpea	-	-	-	-	1.82	-	-
Soybean – Chickpea	-	-	-	-	-	29.76	-

The average cropping pattern of sample households across study districts is detailed in Table 6.5. In the case of Anantapur, only 22% of the rainy season landholding was put under cultivation. Groundnut, paddy, pigeonpea and castor are the dominant crops during the rainy season. In contrast, nearly 71% of the area is under cultivation in the postrainy season, with chickpea and sorghum being the dominant crops at this time. Around 15% of cropped area is under cultivation during rainy season in Kadapa, with cotton and paddy dominating. Chickpea, sorghum and sunflower are some of the major postrainy season crops in the cumulative 77% of total landholding. Cotton, paddy, ajwain and pigeonpea are the dominant crops in Kurnool under rainy season. Chickpea, sorghum and sunflower are major postrainy season crops that occupy nearly 69% of the cropped area.

Maize, pigeonpea, chillies and cotton are the major crops grown in rainy season either under full or partial irrigated conditions in Mahabubnagar. Chickpea and tobacco are the predominant postrainy season crops with maximum share of cropped area. Pigeonpea, green gram, black gram and cotton are some of major rainy season crops in Medak district. But, chickpea, sorghum and coriander are the principle postrainy season crops having significant share of area allocations in Medak district. In case of Nizamabad, rainy season cropping pattern dominated by soybean, green gram, cotton, pigeonpea, black gram and paddy. Chickpea and sorghum are major rabi crops grown significantly in the district. Nearly 90% of the kharif cropped area in Prakasam district was kept fallow and was dominated by chickpea and tobacco during the postrainy season.

Cropping patterns in all seven districts are clearly dominated by postrainy season crops. About 65-70% rainy season croppable area is being kept fallow and subsequently grown with postrainy season crops. Overall, chickpea is the predominant postrainy season crop occupying around 60-70% of the total cropped area.

The details of major crops during postrainy season across different districts are summarized in Table 6.6. Overall, the major crops competing chickpea in the study districts are sorghum, sunflower, black gram, safflower and coriander. Tobacco and maize are other important crops in selected districts. Chickpea has already replaced many of these competing crops significantly.

Table 6.5. Average cropping pattern of sample farmers (ha per household).							
Crops	ANA (N=135)	KAD (N=135)	KUR (N=351)	MAH (N=27)	MED (N=27)	NIZ (N=27)	PRM (N=108)
Rainy (kharif) season							
Groundnut	1.26	0.04	0.12	-	-	-	-
Paddy	0.16	0.24	0.45	-	-	0.16	0.04
Pigeonpea	0.12	0.04	0.20	0.89	0.73	0.65	0.00
Castor	0.12	-	0.12	0.04	-	-	-
Maize	0.04	-	0.12	1.26	0.04	-	-
Chillies	0.04	0.04	0.04	0.28	-	-	0.08
Cotton	0.04	0.53	0.57	0.24	0.28	0.69	0.24
Sorghum	0.04	0.04	0.08	0.04	0.04	0.04	-
Black gram	-	0.04	-	-	0.45	0.61	-
Onion	-	0.04	0.04	-	-	-	-
Ajwain	-	-	0.24	-	-	-	-
Sunflower	-	-	0.08	-	-	-	-
Tobacco	-	-	0.08	0.08	-	-	-
Sugarcane	-	-	-	-	0.08	0.04	-
Green gram	-	-	-	-	0.65	0.93	-
Jute	-	-	-	0.04	-	-	0.20
Soybean	-	-	-	-	0.04	1.38	-
Fallow	6.68	6.36	6.36	4.25	1.66	0.28	4.90
Total	8.54	7.45	8.58	7.13	4.90	4.78	5.51
Postrainy (rabi) season							
Chickpea	5.79	5.18	5.30	3.97	1.82	2.55	3.68
Sorghum	0.12	0.28	0.40	0.04	0.12	0.16	0.04
Sunflower	0.04	0.28	0.16	-	-	-	-
Maize	0.04	0.00	0.00	-	-	-	0.04
Black gram	0.04	0.08	0.04	-	-	-	0.04
Paddy	-	0.04	0.04	-	-	0.04	0.20
Tobacco	-	-	-	0.20	-	-	0.45
Jute	-	-	-	-	-	-	0.12
Safflower	-	-	-	0.04	-	-	-
Coriander	-	-	0.01	-	0.08	-	-
Fallow	2.47	1.58	2.58	2.87	2.83	2.06	0.89
Total	8.55	7.45	8.58	7.13	4.90	4.78	5.51

However, chickpea has the following specific advantages over other crops:

1) New chickpea cultivars provided a short-duration crop
2) Less-labor intensive
3) Relatively low investment per ha is needed
4) Viewed as a less risky crop
5) Assured yields, market and good remunerative prices
6) Highly suitable for mechanical operations
7) Lower pest problems
8) Improves soil fertility
9) Easily cultivable on a large-scale

Due to the above valid reasons, chickpea competitiveness is much higher than any other rainfed crop during postrainy season. The competitiveness of chickpea with other competing crops have been presented and discussed in the subsequent sections of this chapter.

Table 6.6. Crops that compete with chickpea in the postrainy season in the sample districts.

PRM	KUR	KAD	ANA	MED	NIZ	MAH
Paddy	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Tobacco
Jute	Sunflower	Sunflower	Sunflower	Coriander	Paddy	Sorghum
Maize	Black gram	Black gram	Maize		Safflower	Safflower
Black gram			Black gram			
Tobacco						

6.2 Household assets, income and expenditures

Average household assets across study districts

The average assets value of the sample households across study districts is presented in Table 6.7. The average total assets value was USD 1,11,000 per household for the pooled sample. Nearly 85% of the total asset value is contributed by own landholdings. Total livestock value of pooled household contributes hardly 1% to the total. Around 14% of the total assets per household is held by farm equipment, farm buildings and consumer durables. Among the various districts, the total asset value was highest in Kurnool followed by Kadapa and Prakasam districts. The average total asset value per household in these three districts is much higher than the average pooled sample household. The higher total asset values in Kurnool and Kadapa districts was because of larger own-landholding relative to other study districts. Even though Prakasam has smaller size of own-landholding, the per unit land values might be much higher and might have contributed significantly.

Table 6.7. Average household assets (USD ’000 per farmer).								
Item	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Pooled (N=810)
Total land value	91 (80.5)	106 (87.0)	97 (82.9)	69 (83.1)	85 (88.5)	83 (85.5)	80 (86.0)	94 (84.7)
1. Irrigated	6	20	18	6	33	15	21	16
2. Dryland	85	86	79	62	52	68	58	78
3. Fallow land	0	0	0	0	0	0	0	0
Total livestock value	0.87 (0.88)	1.14 (0.82)	0.85 (0.85)	1.12 (1.20)	1.42 (1.04)	1.33 (1.03)	0.92 (1.07)	1.06 (0.90)
Draft	0	0	0	1	0	1	0	0
Buffaloes	1	0	1	0	1	0	0	1
Others	0	0	0	0	0	0	0	0
Total farm equipment	2.49	2.62	2.80	1.56	1.29	0.76	1.26	2.30
Total farm buildings	16.00	9.29	11.83	8.52	5.60	9.25	8.24	10.32
Total consumer durables	2.95	2.77	3.54	2.60	2.84	2.99	2.69	2.90
Total assets value	113 (100.0)	122 (100.0)	117 (100.0)	83 (100.0)	96 (100.0)	97 (100.0)	93 (100.0)	111 (100.0)

The share of irrigated land value in the total land value was only 17% for the pooled sample households. Dryland values contribute significantly (83%) to the total land value of an average household. The value of total livestock was much higher in Medak followed by Nizamabad, Kurnool and Anantapur districts. Farm equipment, farm buildings and consumer durables together added significant value (nearly 19%) to the total assets value in Prakasam district. The average per household farm equipment value was higher in Kadapa district followed Kurnool and Prakasam districts. These values indicate the extent of investments on farm mechanization per household. Farm buildings also contributed significantly in the total asset values in Prakasam district followed by Kadapa and Kurnool. Consumer durables value per average household was higher in Kadapa district than the rest. These higher total asset value per household indicates the strong net worth of chickpea sample households and their potential for agricultural investments.

Average household incomes across sample districts

The average household incomes earned by the sample households during 2011-12 from various sources are summarized in Table 6.8. The average household income of the pooled sample household was USD 3.45 thousand per annum. Around 60% of the total household income was contributed by agriculture. It was followed-up by participation in farm work (8%) and livestock rearing incomes (8%). Non-farm labor participation and Government development programs were together accounting for 9.3% share in the total household income.

Table 6.8. Average household income (USD ’000 per household per annum).

Source of Income	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Agriculture	0.29	3.26	1.27	-0.23	2.73	2.68	4.18	2.03
Farm work	0.28	0.28	0.31	0.33	0.28	0.17	0.31	0.28
Non-farm work	0.16	0.09	0.26	0.28	0.22	0.18	0.11	0.18
Livestock	0.28	0.18	0.29	0.21	0.26	0.23	0.42	0.27
Caste occupations	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Business	0.17	0.19	0.20	0.07	0.05	0.18	0.31	0.17
Migration	0.00	0.03	0.04	0.00	0.00	0.04	0.01	0.02
Remittances	0.09	0.13	0.04	0.07	0.11	0.00	0.09	0.07
Govt. programs	0.12	0.12	0.17	0.14	0.12	0.20	0.09	0.14
Others	0.22	0.54	0.37	0.13	0.18	0.06	0.51	0.29
Total	1.63	4.83	2.96	0.99	3.96	3.74	6.05	3.45

Among sample districts, the average incomes per household were the highest in Prakasam followed by Kadapa, Medak and Nizamabad. The share of agriculture income in the total household income was much higher in Nizamabad (72%) followed by Prakasam (69.2%), Medak (69.1%) and Kadapa (67.6%). The mean agriculture income was negative in Mahabubnagar district due to severe drought in 2011-12. Districts such as Anantapur, Mahabubnagar and Kurnool showed relatively lower incomes than the average pooled household income.

The contribution of livestock sector to the total household income was much significant in Prakasam district. Similarly, household earnings from business sector were also higher in Prakasam followed by Kurnool. The average non-farm labor earnings per household were relatively high in Mahabubnagar and Kurnool districts. The influence of drought on agriculture and average total household earnings was conspicuously high in Anantapur, Kurnool and Mahabubnagar districts.

Average household expenditures across sample districts

The detailed break-up of average household expenditures of the sample households across study districts is presented in Table 6.9. The average expenditure for pooled sample household was 2.4 thousand USD per annum. Total food expenditure alone accounted for 46% of the total expenditure. Non-food expenditure contributed to the remaining share in the pooled sample.

The average total expenditure per household per annum was significantly higher in Prakasam district followed by Nizamabad and Kurnool districts. However, the lowest total expenditure was observed in Mahabubnagar district. The expenditure on total food was slightly lower in Mahabubnagar district. This pattern was more or less similar in other sample districts. Similarly, the expenditure on non-food items was much lower in Mahabubnagar than any other district. This pattern was significantly higher in Prakasam district followed by Nizamabad. The health expenditures per an average household were quite high in Nizamabad while investments on education were much larger in Prakasam district. The expenditure pattern on the other remaining items per household per annum was more or less same across sample households and districts. On average, the pooled sample households spending was nearly 69% of their total earnings as household total expenditures. The remaining 31% might go into household savings and other investments. This is a quite remarkable achievement in SAT environment.

Table 6.9 Average household consumption (USD '000 per household per annum).

Item	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Food expenditure	1.12	1.09	1.19	0.93	1.04	1.15	1.14	1.1
Rice	0.31	0.29	0.30	0.26	0.31	0.29	0.31	0.30
Wheat	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chickpea	0.03	0.02	0.01	0.01	0.02	0.01	0.02	0.02
Pigeonpea	0.05	0.05	0.06	0.04	0.05	0.05	0.04	0.05
Other pulses	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04
Milk	0.19	0.23	0.19	0.18	0.18	0.23	0.23	0.20
Other milk products	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Non-vegetarian	0.09	0.10	0.12	0.09	0.06	0.10	0.08	0.09
Others: food expenditure	0.41	0.36	0.47	0.31	0.37	0.42	0.39	0.39
Non-food expenditure	1.27	1.33	1.34	0.94	1.1	1.43	1.67	1.3
Health	0.37	0.30	0.30	0.17	0.22	0.59	0.35	0.33
Education	0.42	0.57	0.46	0.33	0.37	0.33	0.59	0.44
Clothing	0.14	0.13	0.14	0.11	0.15	0.15	0.17	0.14
Entertainment	0.06	0.06	0.09	0.07	0.08	0.07	0.14	0.08
Ceremonies	0.03	0.02	0.09	0.02	0.03	0.04	0.16	0.06
Others	0.25	0.25	0.26	0.24	0.25	0.25	0.26	0.25
Total	2.40	2.41	2.55	1.87	2.13	2.59	2.81	2.40

Similarly, it would be interesting to understand the socio-economic characteristics of non-chickpea growers from the seven study districts of Andhra Pradesh. The average sizes of land holdings were smaller for non-chickpea growers than chickpea growers. The average annual earnings of household income and consumption expenditures were lower than chickpea sample households. The complete details of non-chickpea households are analyzed and furnished in Appendix 10.

6.3 Importance of chickpea, extent of adoption, yields and cost of production

Importance of chickpea in sample households

The relative importance of chickpea in the sample households is critically analyzed and presented in the Table 6.10. Of the total pooled area of the sample, only 24% of land is being utilized for crops cultivation in the rainy season. The remaining 76% cropped area is used for cultivating the postrainy season crops. All the study districts and sample households have a predominant postrainy season cropping pattern rather than rainy season. Wherever farmers have some irrigation facilities or better rainfall regime, they prefer to grow soybean, green gram, black gram, maize, paddy and cotton crops.

Of the total rabi season cropped area, nearly 88.2% area has been allocated to chickpea alone. Tobacco, sorghum, sunflower and safflower occupied the remaining 11.8% area at this time. This indicates the relative importance of chickpea in farmers' livelihood and household earnings. Chickpea as a single dominant crop has occupied nearly 67% share of total cropped area in the entire sample households. This statistic clearly sends support to the statement that Andhra Pradesh has achieved a 'chickpea revolution' during the last two decades.

Table 6.10 Importance of chickpea in sample households (ha).

Item	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Total
Total cropped area	605.1	3018.9	1005.7	1083.5	176.2	200.4	192.1	6279.8
Area under kharif (rainy)	63.4	764.8	149.9	251.7	85.9	121.3	77.7	1512.1
Area under rabi (postrainy)	541.7	2254.1	855.7	831.7	90.2	79.1	114.3	4767.6
Chickpea cropped area	444.5	1991.5	751.0	793.1	49.3	71.6	107.1	4208.4
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
1. Own land	223.4	1527.1	617.2	614.7	43.3	50.6	81.3	3157.9
	(50.3)	(76.7)	(82.8)	(77.5)	(87.7)	(70.6)	(75.9)	(75.0)
2. Leased-in land	221.1	464.3	133.8	178.3	6.0	21.0	25.7	1050.4
	(49.7)	(23.3)	(17.2)	(22.5)	(12.3)	(29.4)	(24.1)	(25.0)
% chickpea in postrainy area	82.1	88.3	87.7	95.3	54.7	90.5	93.6	88.2
% chickpea in cropped area	73.4	66.0	74.7	73.2	28.0	35.7	55.7	67.0

Note: Figures in parenthesis indicate percentage to total

Overall, about 75% of the total chickpea cropped area came from farmers' own land. Nearly one quarter of cropped area coming from other crops (other than chickpea) has been substituted by chickpea. These high proportions were even more conspicuous in Prakasam where nearly half of the total cropped area came from leased-in land. In the remaining districts, the extent ranges from 15 to 25%.

Among the study districts, chickpea has the highest dominance in the postrainy season cropping pattern in Anantapur followed by Mahabubnagar, Nizamabad, Kurnool and Kadapa. Relatively, the lowest importance was observed in Medak district (around 55% only).

First year of adoption and adoption lag

The sample farmers were asked to elucidate about the first adoption pattern of various chickpea short-duration cultivars during the household interviews. Based on their recall and feedback, the first adoption pattern of prominent short-duration chickpea cultivars is summarized in Tables from 6.11a to 6.11d respectively for Annigeri, JG 11, KAK 2 and Vihar. These results really bring us to better understand the various patterns of adoption across cultivars, as well as help identify the differential adoption behavior among the sample districts.

Table 6.11a. First adoption pattern of Annigeri cultivar among sample districts (No.).								
Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 1995	7	19	0	6	11	0	0	43
1996-2000	17	57	32	24	6	0	3	139
2001-2005	25	188	48	64	8	15	16	364
2006-2010	1	25	13	11	2	12	3	67
After 2010	0	0	0	0	0	0	0	0
Total*	50	289	93	105	27	27	22	613

* Differences in total and sample are non-adopters of Annigeri.

The details of first adoption pattern of Annigeri across sample households are presented in Table 6.11a. 'Annigeri', an improved landrace selection was formally released during 1978 in Karnataka. Subsequently, the cultivar entered Andhra Pradesh during the early 1990s. Overall, nearly 76% of the sample households first adopted Annigeri at differential points of time. About 45% of the total sample adopted it between 2001 and 2005. A number 182 out of the 810 (nearly 23%) sample households adopted Annigeri before 2000. The availability of medium duration varieties (Annigeri) initially paved the way for chickpea penetration in the study districts between early 1990s and 2000s. Sample farmers from Kurnool, Prakasam and Medak districts are early adopters of the new cultivars.

Table 6.11b. First adoption pattern of JG 11 cultivar among sample districts (No.).								
Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	2	2	0	0	0	0	0	4
2001-2005	45	70	8	8	0	0	2	133
2006-2010	42	272	123	123	12	21	24	617
After 2010	2	3	4	2	1	0	0	12
Total*	91	347	135	133	13	21	26	766

* Differences in total and sample are non-adopters of JG 11.

The details of the first adoption pattern of JG 11 across sample districts are summarized in Table 6.11b. The short-duration improved desi type cultivar JG 11 was released in 1999. The initial adoption patterns started since early 2000s. Nearly 95% of the total sample farmers first adopted JG 11 from late 1990s up to 2011. However, a huge chunk of sample (76%) farmers adopted it between 2006 and 2010. The majority of the adopters between 2001 and 2005 belong to Prakasam and Kurnool districts. Development and availability of early maturing cultivars (JG 11 and KAK 2) further spur the chickpea expansion in the state. Major shares of Kurnool, Kadapa and Anantapur district sample farmers first adopted JG 11 during 2006-2010. Out of the total 810 farmers, very few (2%) joined the JG 11 adopters' group as late as after 2010.

Table 6.11c. First adoption pattern of KAK 2 cultivar among sample districts (no.).								
Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	0	0	0	0	0	0	0	0
2001-2005	29	5	0	0	0	0	0	34
2006-2010	57	16	4	0	0	0	0	77
After 2010	1	2	0	0	0	0	0	3
Total	87	23	4	0	0	0	0	144

* Differences in total and sample are non-adopters of KAK 2.

The details of first adoption pattern of KAK 2 across sample districts are presented in Table 6.13c. The short-duration improved kabuli type KAK 2 cultivar was formally released in 1998. Only 18% of the total sample farmers first adopted KAK 2 over the last decade. Majority (60%) of KAK 2 adopters belong to Prakasam district followed by Kurnool (3%), and they were the only adopters of KAK 2 between 2001 and 2005. In fact, adoption rates of KAK 2 peaked between 2006 and 2010.

The patterns of first adoption of Vihar across sample districts are summarized in Table 6.11d. 'Vihar' is an improved short-duration kabuli type cultivar formally released in 2002. Around 12% of the total sample first adopted Vihar between 2001 and 2011. Most of the adopter farmers (57%) belong to Kurnool district followed by Kadapa and Prakasam. The peak rate of adoption was found during 2006 and 2011.

Table 6.11d. First adoption pattern of Vihar cultivar among sample districts (No.).								
Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	0	0	0	0	0	0	0	0
2001-2005	4	6	3	0	0	0	0	13
2006-2010	4	34	14	0	0	0	1	53
After 2010	0	15	14	1	0	0	0	30
Total	8	55	31	1	0	0	1	96

* Differences in total and sample are non-adopters of Vihar.

The details of first adoption area of the sample farmers under each improved cultivars are illustrated in Figure 6.1. Similarly, the cumulative number of farmers in the sample who adopted over time is depicted in Figure 6.2. The adoption of Annigeri started in early 1990s and reached its peak in 2002 and after that it went down slowly. However, the adoption of JG 11 started in early 2000s and reached its peak around 2009. KAK 2 and Vihar started a little later but did not occupy much area in the sample. Figure 6.2 clearly confirms that from initial adoption to reaching its peak adoption, it took almost 17 years for Annigeri; whereas JG 11 reached the same peak with a span of 9 years. It is a remarkable achievement for JG 11 in Andhra Pradesh.

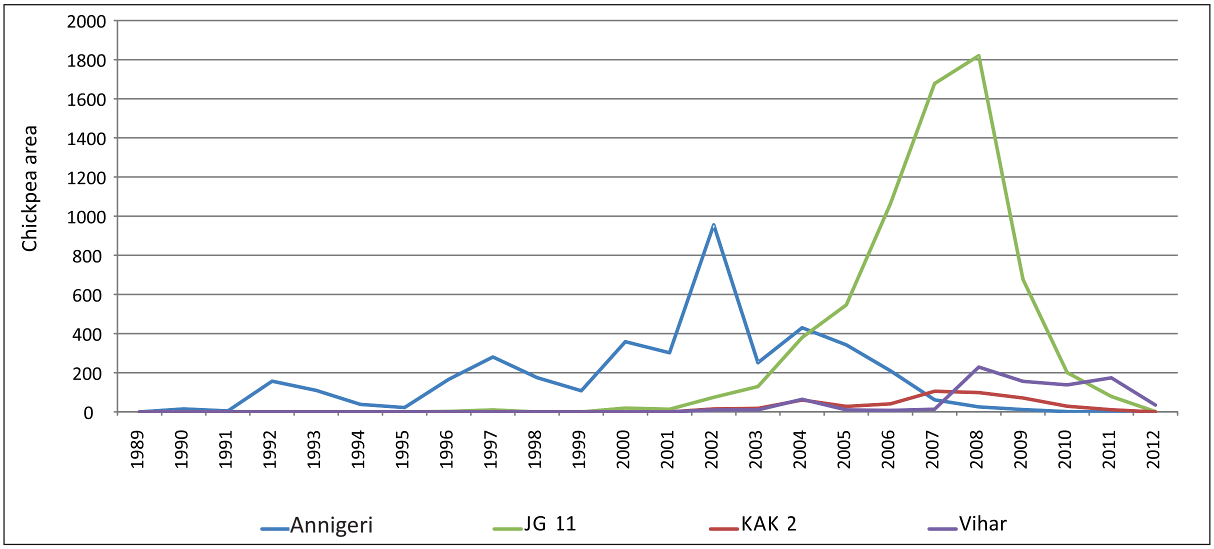

Figure 6.1. First adoption of improved cultivars of chickpea in the sample (area in acres).

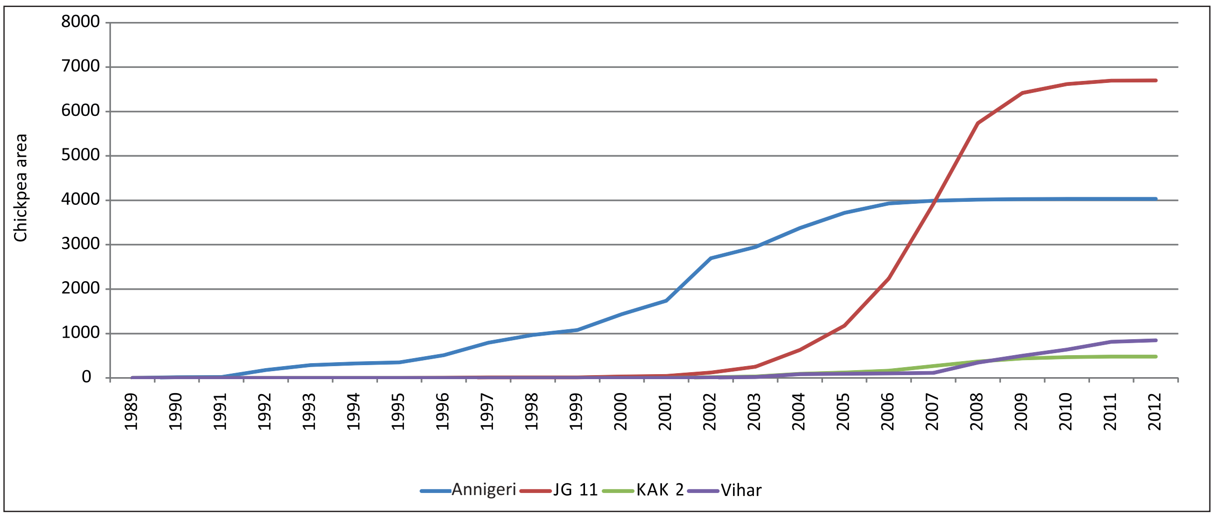

Figure 6.2. Cumulative first adoption area of improved cultivars by sample (area in acres).

Figures 6.3 and 6.4 illustrate the first adoption pattern based on the number of sample farmers adopting a particular cultivar at a specific point of time and the cumulative numbers over the study period respectively. Over all, similar trends for adoption of short-duration improved cultivars are depicted.

Figure 6.5 presents the average time lag (from 1999 to first adoption) taken by each study district for the adoption of JG 11 improved cultivars. The average time lag was calculated based on cumulating each JG 11 adopter time lag in a district and dividing that by the number of JG 11 adopters in that particular district (detailed formulae furnished in Appendix 11). The lowest time lag was observed in Prakasam while the longest time lag was observed in Medak. All the other districts exhibited the ranges in between 6 to 10 years. These results clearly lend the support for differential uptake of JG 11 across districts in Andhra Pradesh.

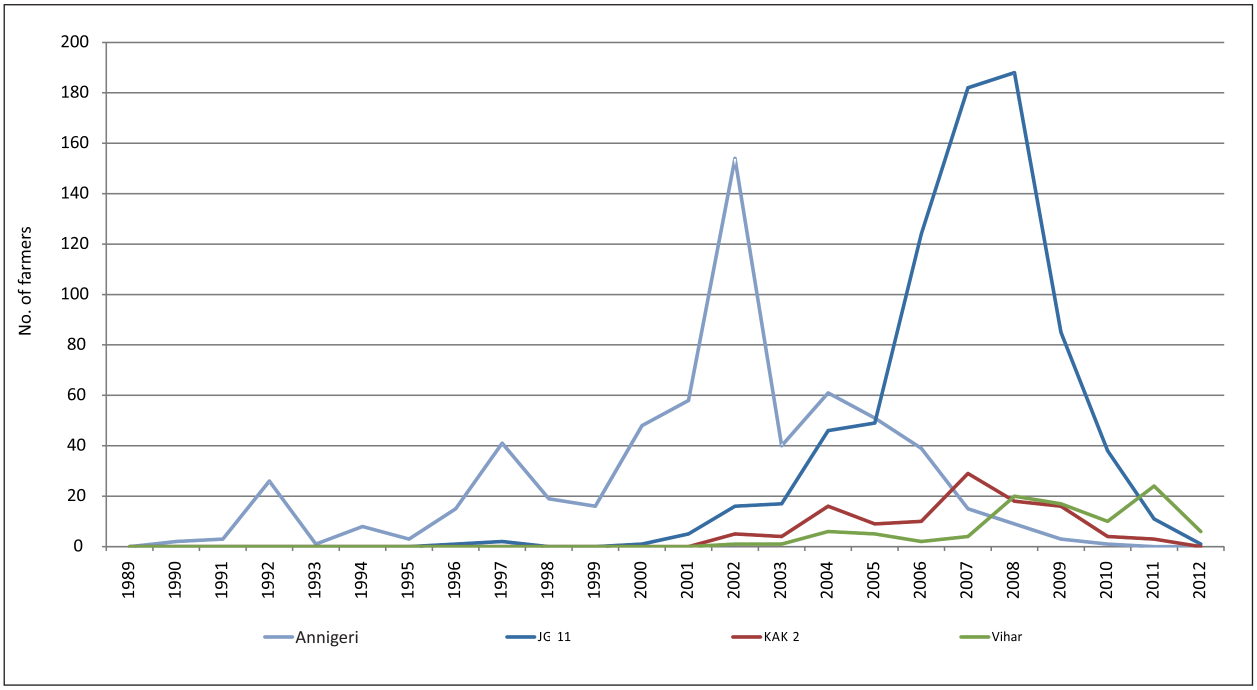

Figure 6.3. First adoption of chickpea improved cultivars in the sample (no. of farmers).

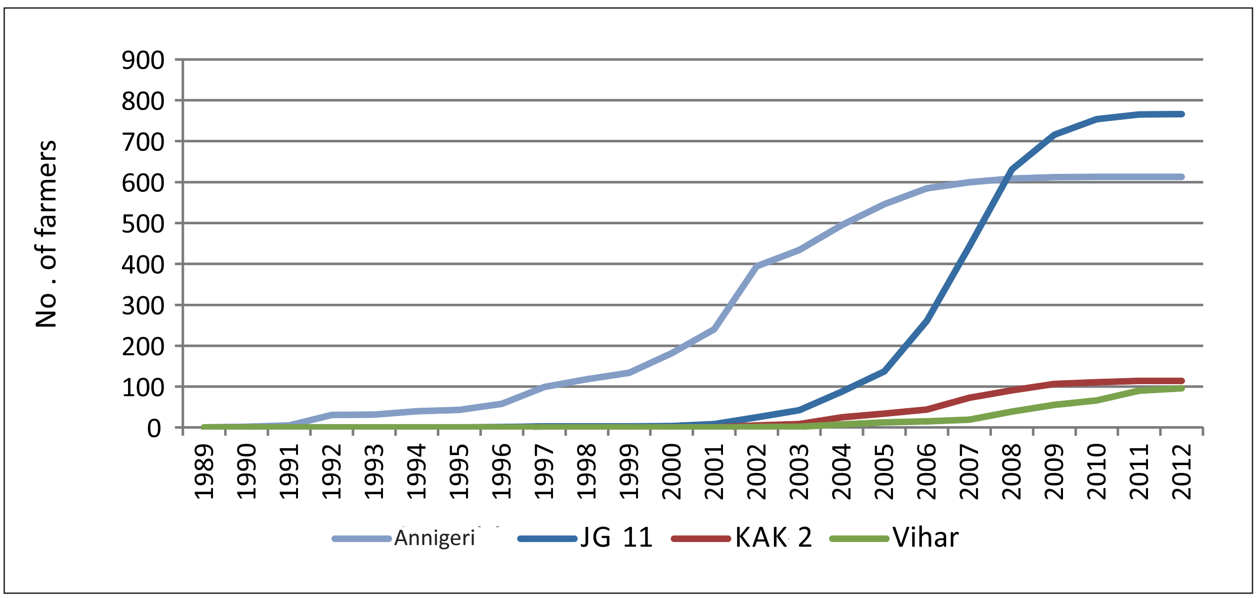

Figure 6.4. Cumulative first adoption of improved cultivars by sample farmers (no. of farmers).

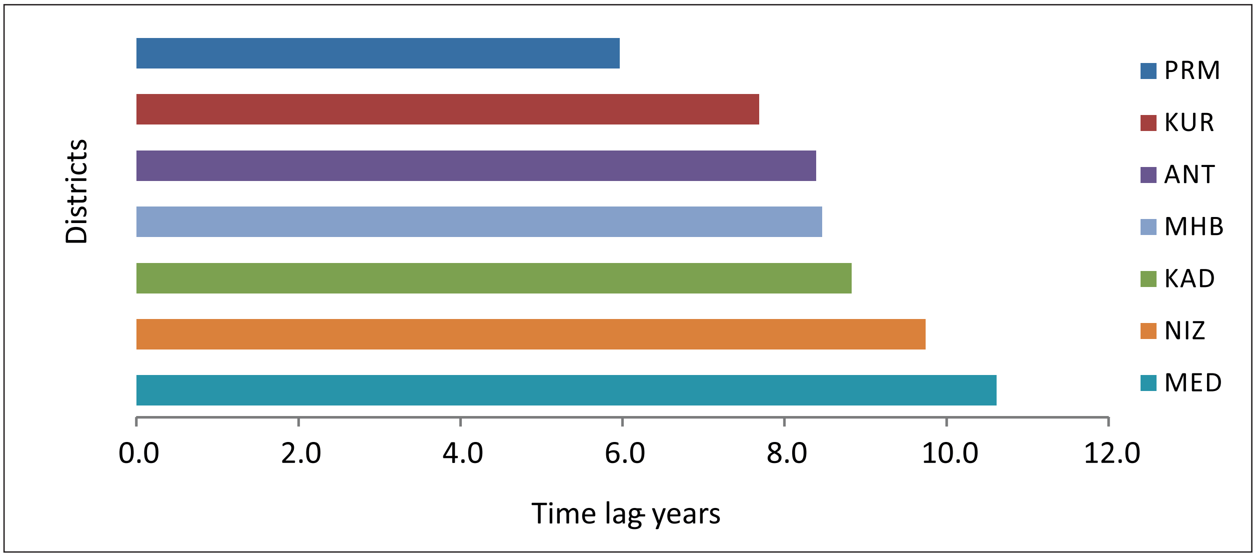

Figure 6.5. Average time lag for adoption of JG 11 among sample farmers.

Table 6.12. First adoption sources of information and seeds (% farmers).

	Variety – JG 11			
	Main source of information		Main source of first seed	
District	FF*	GE*	VS*	LS*
PRM	72.2	17.5	49.5	27.8
KUR	82.0	12.0	66.6	17.1
KAD	94.1	3.0	94.8	0.0
ANA	81.5	14.1	81.5	1.5
MED	68.2	31.8	45.5	0.0
MAH	96.2	3.8	96.2	0.0
NIZ	91.7	4.2	70.8	0.0
Total	83.1	11.5	72.4	11.3

*FF: Fellow Farmer
*GE: Government Extension Agency
*VS: Villagers
*LS: Local Seed Traders

The details about major sources of information and major sources of first seed of JG 11 are summarized in Table 6.12. The results clearly conclude that the main source of information for JG 11 were fellow farmers (83%) followed by government extension agencies (12%). Nearly 75% of JG 11 first seed requirements were met by the villagers themselves. However, another 12% of the first seed was purchased from local seed traders. Nevertheless, farmers were also dependent on some other sources of information and first seed but those were not summarized and reported in this table.

Area allocation under chickpea cultivation

The details about area allocation to chickpea crop by sample farmers during the last three seasons are summarized in Table 6.13. During the household interview, farmers were asked to answer about area allocation pattern to chickpea during the last three consecutive years. On the whole, around 74% of total farmers expressed that their area allocation to chickpea crop was constant. Another 20% sample farmers indicated that they are increasing area allocation to chickpea over the time. Only negligible share of farmers (7%) pointed out a decreasing area allocation to chickpea. These farmers might get access to irrigation and hence have moved away from chickpea to other commercial crops. However, more or less the same trends were observed across districts.

Table 6.13. Allocation of chickpea area during the last three seasons (2009-12).

District	Area trend (no. of farmers)				Crops replaced by chickpea
	Increasing	Decreasing	Constant	Total	
Prakasam (N=108)	29 (26.9)	3 (2.8)	76 (70.4)	108 (100.0)	Cotton, Tobacco
Kurnool (N=351)	78 (22.2)	23 (6.6)	250 (71.2)	351 100.0)	Sunflower
Anantapur (N=135)	10 (7.4)	19 (14.1)	106 (78.5)	135 (100.0)	Groundnut
Kadapa (N=135)	28 (20.7)	3 (2.2)	104 (77.0)	135 (100.0)	Groundnut
Nizamabad (N=27)	7 (25.9)	0 (0.0)	20 (74.1)	27 (100.0)	Sorghum
Medak (N=27)	1 (3.7)	7 (25.9)	19 (70.4)	27 (100.0)	-
Mahabubnagar (N=27)	5 (18.5)	2 (7.4)	20 (74.1)	27 (100.0)	Sunflower
Total sample (N=810)	158 (19.5)	57 (7.0)	595 (73.5)	810 (100.0)	-

Note: Figures in the parenthesis are percentages to row totals.

Diffusion and adoption of short-duration improved chickpea cultivars

The information about cultivar specific adoption estimates for three consecutive years is summarized in Table 6.14 The area allocations by sample farmers across three cropping seasons to improved cultivars were rather stable. Around 10% increase in area expansion under chickpea was observed between 2009 and 2011. A huge chunk of area (85%) has been allocated to only JG 11 cultivar (see also Figure 6.6). It is the single-most dominant improved cultivar in the state. It was followed by Vihar (7%) and KAK 2 (6%). The old improved cultivar 'Annigeri' has a little presence (2%) in Medak and Nizamabad districts. Other cultivars such as JAKI 9218 and JG 130 have very negligible shares. Dollar (BOLD), another informal kabuli type has some presence in Prakasam district. Overall, nearly 98% of chickpea area in the state was under improved cultivars by 2011.

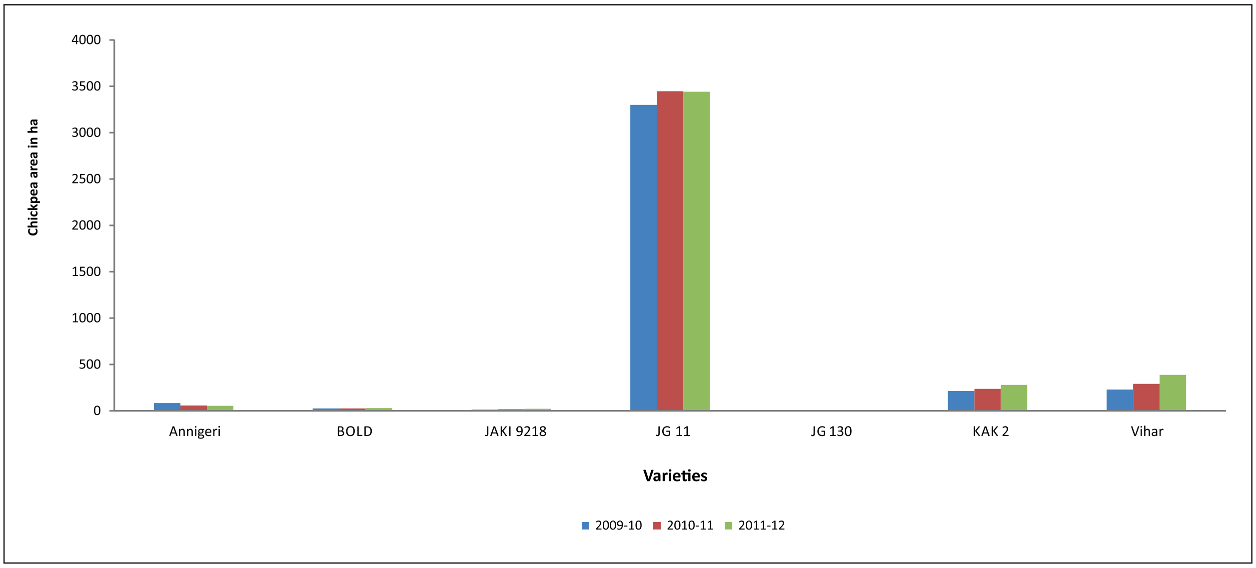

Figure 6.6. Area allocation of chickpea area under different cultivars, 2009-12.

Table 6.14. Allocation of area under different chickpea cultivars, 2009-12 (ha).

Cultivar name	Area in 2009-10	Area in 2010-11	Area in 2011-12	Average (2009-12)
Annigeri	80.16 (2.0)	53.44 (1.3)	49.80 (1.2)	61.13 (1.52)
Dollar (BOLD)	21.46 (0.5)	21.86 (0.5)	25.91 (0.6)	23.08 (0.57)
JAKI 9218	7.69 (0.2)	11.74 (0.3)	18.62 (0.4)	12.67 (0.31)
JG 11	3294.33 (85.8)	3443.32 (84.9)	3436.84 (81.9)	3391.50 (84.19)
JG 130	0 (0.0)	4.86 (0.1)	4.86 (0.1)	3.24 (0.08)
KAK 2	209.31 (5.4)	231.98 (5.7)	274.90 (6.6)	238.70 (5.92)
Vihar (Phule-G)	224.29 (5.8)	285.83 (7.0)	383.40 (9.1)	297.85 (7.39)
Total	3837.25 (100.0)	4052.63 (100.0)	4194.74 (100.0)	4028.18 (100.0)

Note: Figures in the parenthesis are percentages to column total.

Comparison of survey results and elicitation process

It is clear from Table 6.15 that desi JG 11 has reached very high adoption rates in the south western districts of Kurnool, Anantapur, Kadapa and Mahabubnagar; while kabuli KAK 2 is already covering 58% of Prakasam in the coastal belt of Andhra Pradesh. A wide variation in adoption pattern is revealed as diffusion to the northern districts is seen to be just starting. For example, the traditional Annigeri variety is still grown in about 40% of the chickpea cropped area in Nizamabad and Medak. Vihar is another dominant kabuli type grown mostly in Kadapa and Kurnool districts of Andhra Pradesh.

Table 6.15. District-wise chickpea area under different cultivars (% area), 2011-2012.								
District	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Desi types								
Annigeri	0	0	0.1	0	38.1	40.7	0	1.2
JAKI 9218	1.9	0.4	0	0	0	0	0	0.4
JG 11	97.5	79.4	87.7	100	61.9	59.3	33.9	81.9
JG 130	0.6	0	0	0	0	0	0	0.1
Kabuli types								
KAK 2	0	0.8	0.6	0	0	0	58	6.6
Vihar	0	19.4	11.6	0	0	0	2.2	9.1
Dollar (BOLD)	0	0	0	0	0	0	5.9	0.6
Total	100	100	100	100	100	100	100	100

Source: Primary household survey in Andhra Pradesh conducted in 2013, with reference to 2011-12 cropping season.

Table 6.16 contrasts the estimates drawn from the sample with the expert opinion elicited the year before through the TRIVSA Project (2011) covering all ICRISAT mandate crops for all relevant states in India. A comparative analysis can be drawn using the data in Table 6.15 as benchmark, ie, comparing the implications of the elicited data from expert stakeholders to the findings from the primary farm survey data. Indirectly, this measures the additional value of the survey generating refined disaggregated data.

Table 6.16. Expert elicitations on adoption of improved cultivars in AP.		
Cultivar	Release year	% area in AP
JG 11	1999	70
KAK 2	1999	20
Annigeri	1978	3
Extra bold kabuli types (Dollar, Bhema etc.)	-	2
All MVs		95

Source: ICRISAT TRIVSA Project elicitations, 2011.

It seems that the panel of experts (comprising primarily of breeders and scientists) were relatively conservative in their estimates of the coverage of JG 11 (Table 6.16). The elicitation process revealed the experts rough estimate of 70% adoption specifically of JG 11 variety versus 82% JG 11 adoption level estimated from the survey data. On the other hand, the expert elicitation tended to overestimate the adoption level of KAK 2 (ie, 20% adoption estimated during the expert elicitations versus only 7% estimated from the survey data).

Details about the pattern of adoption by sample farmers district-wise are presented in Table 6.17. Nearly 78% of the total sample farmers adopted JG 11 in their farms. It was followed by KAK 2 (9.4%) and Vihar (8%). Some of the sample farmers in Prakasam, Kurnool and Kadapa districts are growing more than one improved cultivar of chickpea on their farms. So this led to double counting of the same farmers under those varieties (gone up to 908 from 810). Around 3% of sample farmers were found to be still growing 'Annigeri' in the pockets of Medak and Nizamabad districts. Overall, 96% of the total sample farmers allocated their chickpea area to improved cultivars.

Table 6.17. District-wise adoption pattern of improved cultivars (no. of farmers).

Variety	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Annigeri	0	0	2 (2)	0	15 (15)	12 (17)	0	27 (34)
JG 11	131 (228)	123 (231)	331 (594)	27 (43)	14 (15)	18 (35)	60 (89)	704 (1235)
KAK 2	0	1 (2)	5 (6)	0	0	0	79 (128)	85 (136)
Vihar	0	25 (47)	47 (81)	0	0	0	2 (2)	74 (130)
JAKI 9218	3 (6)	1 (1)	0	0	0	0	0	4 (7)
JG 130	2 (5)	0	0	0	0	0	0	2 (5)
Dollar	0	0	0	0	0	0	12 (14)	12 (14)
Total	136* (239)	150* (281)	385* (683)	27 (43)	29* (30)	30* (52)	153* (233)	908* (1561)

Note: Figures in the parenthesis indicates no. of plots.
* Farmers growing more than one variety.

Table 6.18. Major sources of improved cultivars seeds during 2011-12.

District	JG 11	Major source code	KAK 2	Major Source code	Vihar	Major source code
Prakasam	JG 11	5, 10	KAK 2	5	Vihar	5
Kurnool	JG 11	5, 10	KAK 2	5	Vihar	5
Anantapur	JG 11	5, 10	-	-	-	-
Kadapa	JG 11	5, 10	-	-		5
Nizamabad	JG 11	5, 10	-	-	-	-
Medak	JG 11	5, 10	-	-	-	-
Mahabubnagar	JG 11	5, 10	-	-	-	-

Code 5: Bought from villagers; Code 10: Subsidized government seed scheme

Table 6.18 outlines major sources of seeds for improved cultivars during 2011-12. Overall, two major forces are working in favor of the rapid spread of improved seeds in Andhra Pradesh. They are: a) the Government's seed subsidy program; and b) Buying seeds from villagers/neighbors. The Government of Andhra Pradesh with the help of Andhra Pradesh State Seeds Development Corporation (APSSDC) multiplied huge quantities of JG 11 seed and provided on subsidy to encourage adoption in the state. Only public sector organizations such as APSSDC, National Seeds Corporation (NSC), ANGRAU (Acharya NG Ranga Agricultural University) and SFCI (State Farm Corporation of India Ltd) are involved in multiplication, production and marketing in the state. None of the private seed companies are involved in seed production and multiplication. However, seed purchasing from villagers or neighboring farmers is the most common practice (around 88%)

in case of chickpea. A few farmers (10%) are only using the subsidized seed for planting purposes. Since chickpea is a self-pollinated crop, the seeds can be rotated safely for up to three years. Strong policy encouragement coupled with the highly innovative nature of the farmers has helped Andhra Pradesh in achieving this revolution in chickpea.

Adoption pathways of short-duration improved cultivars across districts

The adoption pathways of short-duration improved cultivars across sample districts are illustrated in Figures 6.7 to 6.13. The cumulative number of adopters are shown by cultivar and time period across different study districts. Prakasam and Kurnool districts are the fore-runners for short-duration technology adoption in the state. Kadapa and Anantapur joined the adopters group a little later. Mahabubnagar closely followed Kurnool district along with Anantapur. Nizamabad and Medak districts are the laggards in adoption of these cultivars. The district-wise differential adoption patterns can be clearly seen by moving from Figure 6.7 to 6.13.

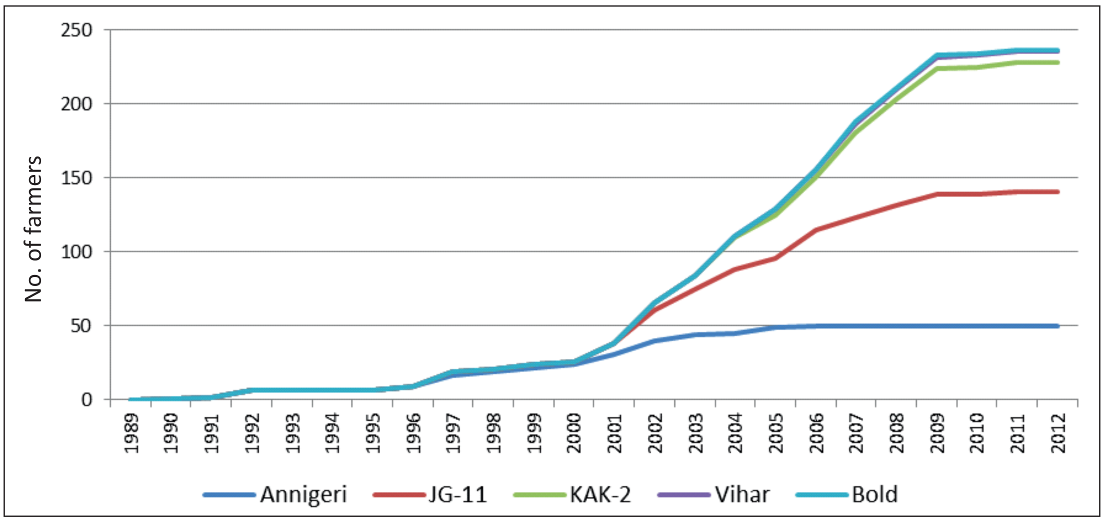

Figure 6.7. Adoption pathway in Prakasam district by sample farmers (cumulative number).

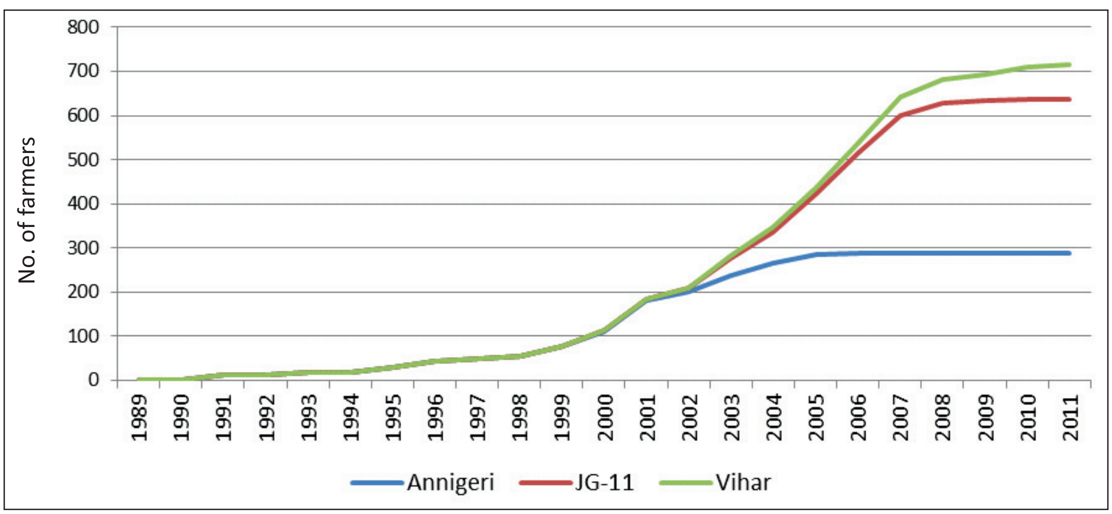

Figure 6.8. Diffusion pathway in Kurnool district by sample farmers (cumulative number).

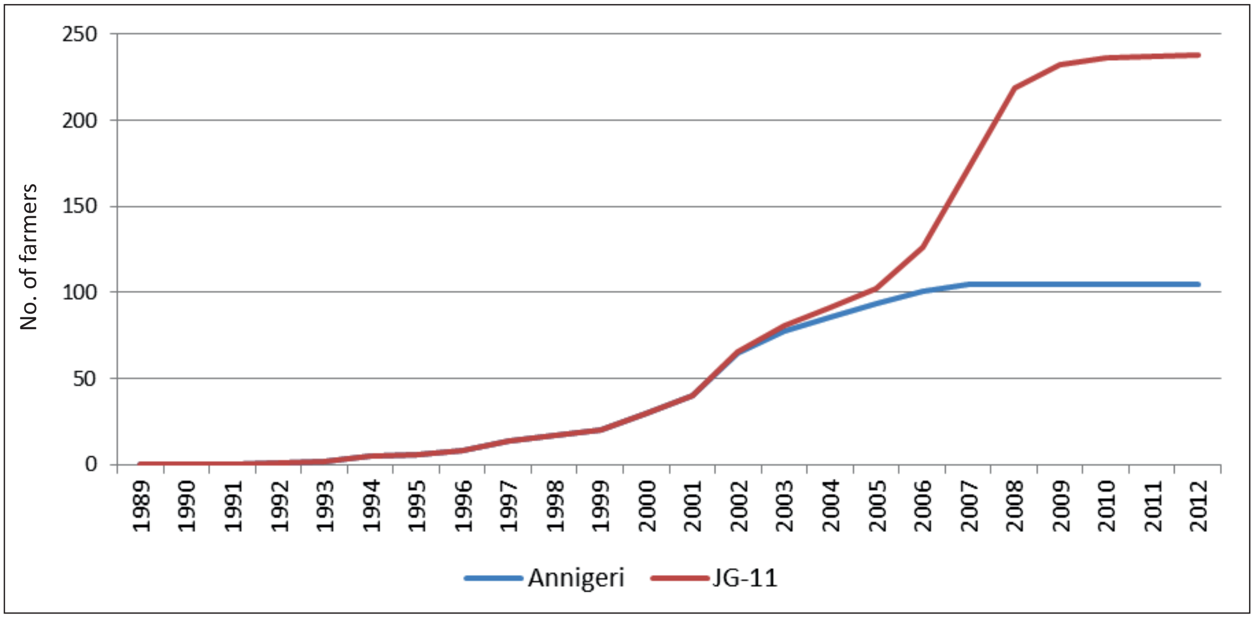

Figure 6.9. Adoption pathway in Anantapur district by sample farmers (cumulative number).

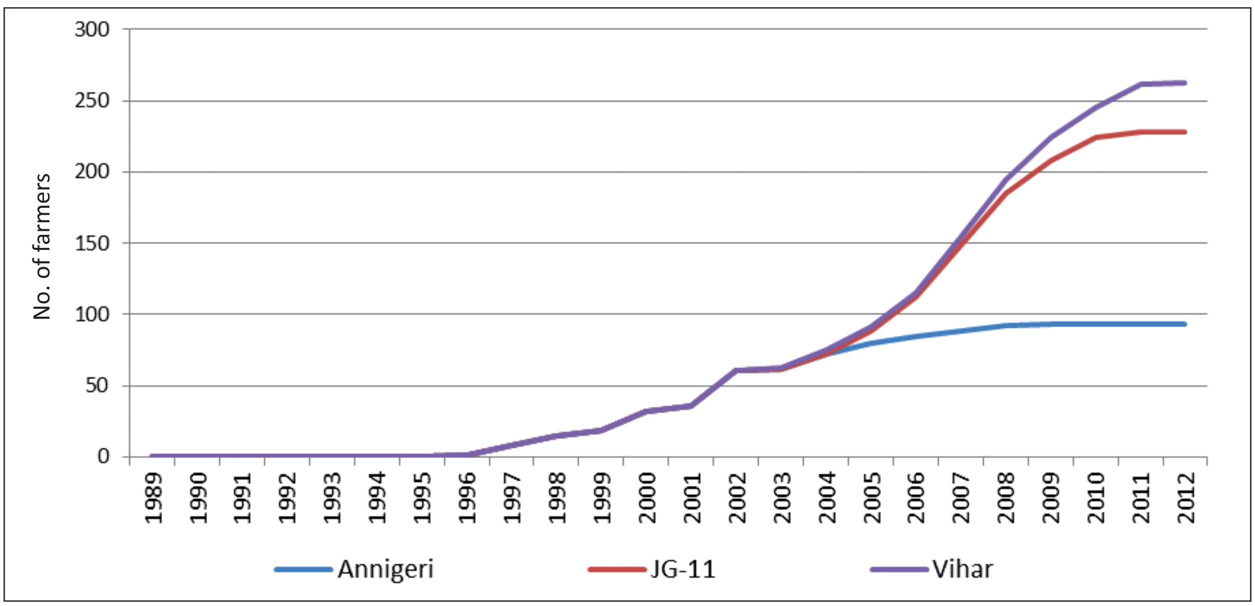

Figure 6.10. Adoption pathway in Kadapa district by sample farmers (cumulative number).

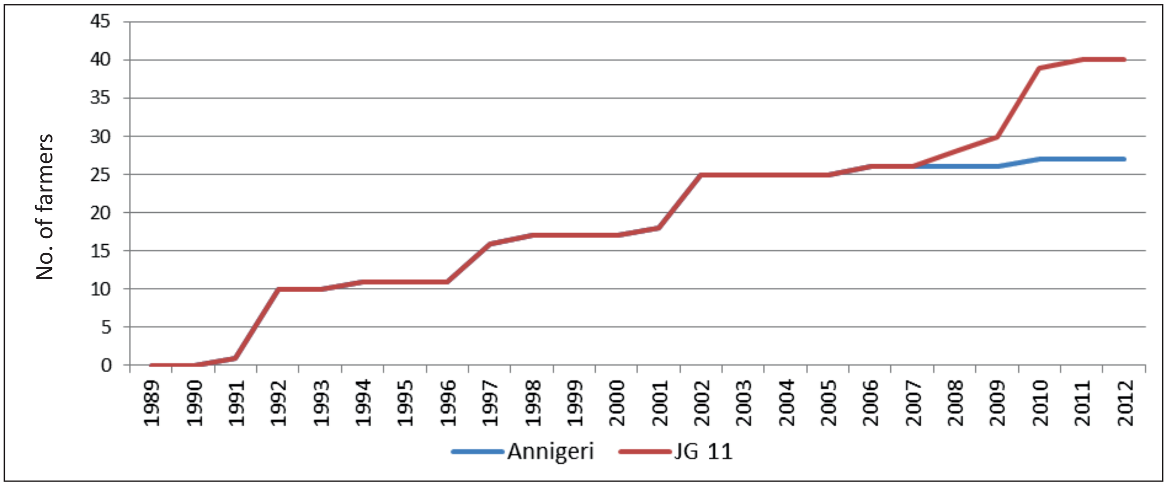

Figure 6.11. Adoption pathway in Medak district by sample farmers (cumulative number).

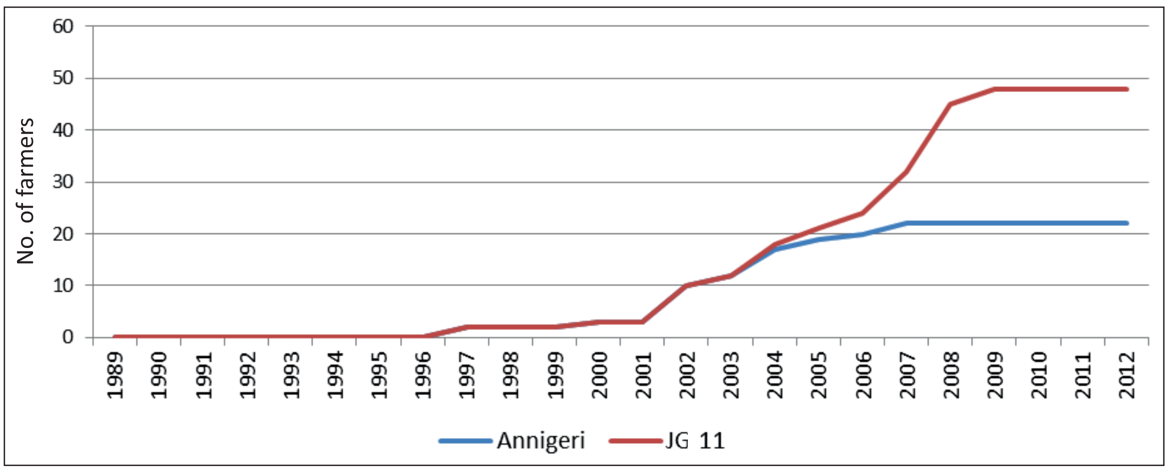

Figure 6.12. Adoption pathway in Mahabubnagar district by sample farmers (cumulative number).

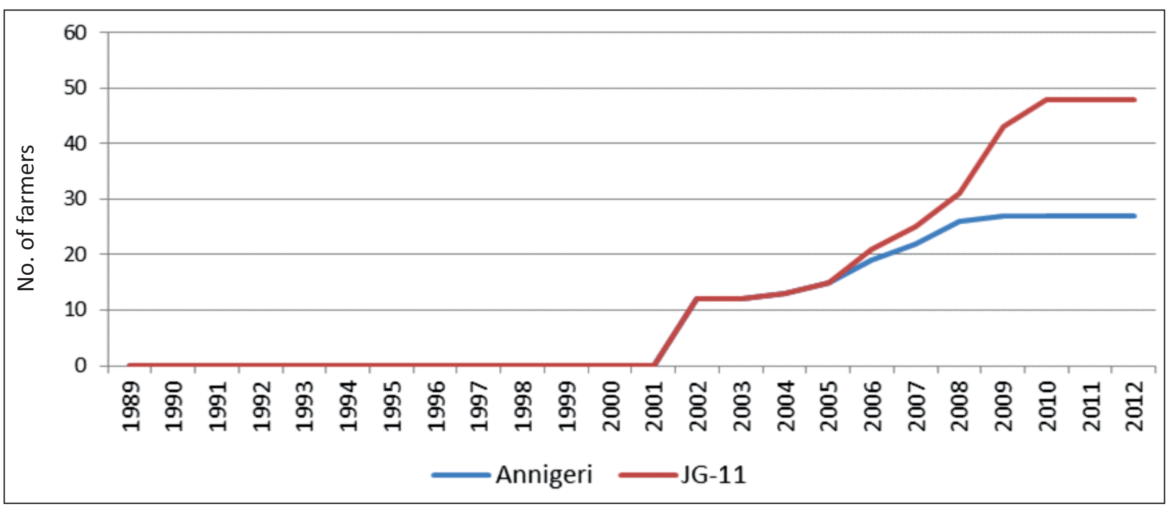

Figure 6.13. Adoption pathway in Nizamabad district by sample farmers (cumulative number).

Further, the variety-wise initial adoption of sample farmers over the period and their respective area allocation by district-wise are furnished in Appendix 12.

Average productivity levels of chickpea in study districts

The average productivity levels of chickpea in study districts are presented in Table 6.19. The data shows the geographical differences in chickpea yields based on cultivar type and perceptions of sample farmers. Under normal conditions, Annigeri used to produce an average yield of 1062 kg per ha. But the new improved chickpea cultivar generates a mean yield of 1583 kg per ha, which means that nearly 40-50% yield advantage has been noticed with the switch from Annigeri to JG 11. The highest yield increase was observed in Kadapa district followed by Anantapur and Kurnool. The lowest yield benefit was noticed in Nizamabad and Medak. Low yield differences may be the reason for low adoption of JG 11 in these two districts. The extent of yield deviations due to climatic aberrations was much similar in both Annigeri and JG 11. The kabuli type KAK 2 was most preferred only in Prakasam while another kabuli type Vihar was much adopted in Kurnool and Kadapa districts. Overall, the performance of KAK 2 was better than Vihar in Andhra Pradesh. In general, the highest productivity levels across cultivars were observed in case of Prakasam district.

Table 6.19. Average chickpea yields under different climatic situations (kg per ha).

	Annigeri			JG 11			KAK 2			Vihar		
District	Normal	Low	Best	Normal	Low	Best	Normal	Low	Best	Normal	Low	Best
PRM	1480	1097	1855	2114	1556	2623	1919	1408	2369	-	-	-
KUR	1074	593	1492	1606	632	2127	-	-	-	1591	1032	2045
ANA	798	324	1099	1203	368	1692	-	-	-	-	-	-
KAD	837	371	1198	1450	776	1907	-	-	-	1554	687	1988
NIZ	1680	1013	2060	1865	1233	2048	-	-	-	-	-	-
MED	1324	776	1739	1598	1107	2100	-	-	-	-	-	-
MAH	1099	454	2211	1568	393	2082	-	-	-	-	-	-
Overall	1062	566	1435	1583	729	2139	1773	1284	2428	1541	941	1969

6.4 Comparison of improved cultivar yields from on-station trial data

The performance of chickpea improved cultivars under various on-station trials are summarized in Tables from 6.20 and 6.24. The data clearly visualize the yield potential of JG 11 when compared the old variety 'Annigeri' at Nandyal Research Station located in Kurnool district of Andhra Pradesh. In case of Initial Varietal Trial (IVT) conducted during 2008-09 among desi type exhibits nearly 36 percent increase in yield per ha between JG 11 and Annigeri cultivars. These findings were confirmed in the subsequent International Chickpea Screening Nurseries (ICSN) conducted at Nandyal (see Tables 6.21, 6.23 and 6.24).

Table 6.20. Performance of improved cultivars in Initial Varietal Trial (desi, Rabi: 2008-09).

Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/ Plot	Final Plant Population/ Plot	Plant Height	Number of Pods per plant	Pod borer	Yield/ Plot	100 Seed Weight (g)	Seed yield (kg/ha)
NBEG-84	50	102	18	15	45.1	47.8	0.30	319.7	25.5	2880
NBEG-89	48	97	26	23	40.1	44.7	1.20	241.3	24.3	2174
NBEG-90	48	92	26	23	39.7	35.1	1.00	224.0	25.3	2018
JG-11 (C)	47	97	30	28	37.8	48.7	0.40	220.3	24.3	1985
NBEG-86	49	102	22	19	42.4	38.6	0.20	201.7	24.8	1817
NBEG-85	47	92	21	19	33.9	38.5	1.20	199.3	25.3	1796
NBEG-82	48	100	17	15	39.5	50.8	0.20	193.0	25.5	1739
NBEG-81	47	99	18	16	38.0	37.3	0.90	178.3	25.2	1606
NBEG-87	48	95	22	20	37.6	40.8	0.40	166.3	24.2	1498
Annigeri ©	50	103	16	13	44.9	45.0	1.40	162.2	21.5	1461
NBEG-91	43	91	18	15	39.7	28.5	0.10	144.5	26.5	1302
NBEG-94	41	92	20	19	39.1	32.6	0.30	126.7	26.2	1141
NBEG-95	43	98	16	14	42.4	38.3	0.80	113.6	25.5	1023
Grand Mean	46	97	20	18	40.0	40.5	0.64	191.6	24.9	1862
SEm ±	0.138	1.214	3.328	3.500	2.544	5.714		36.780	0.417	165.5
CD at P ≤ 0.05	0.300	2.65	NS	NS	NS	NS		80.14	0.908	360.6
CV %	0.42	1.77	22.50	26.58	8.99	19.95		27.15	2.37	27.15

Date of sowing: 27-10-2008 at Nandyal Research Station, ANGARU

Source: Personal communication from Dr V Jayalakshmi

Table 6.21. Performance of improved cultivars in International Chickpea Screening Nurseries (desi, Rabi: 2008-09).

S.No	Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/ Plot	Final Plant Population/ Plot	Number of Pods per plant	Pod borer	Yield/ Plot	100 Seed Weight (g)	Seed yield (kg/ha)	Seed yield (kg/ ha) Adjusted
1.	ICCV-07117	44	89	48	39	40.2	0.0	561.5	28.0	2529	2509
2.	ICCV-08101	46	92	43	41	52.3	0.0	535.3	23.1	2411	2362
3.	ICCV-08108	50	93	42	36	57.4	0.1	477.2	22.1	2149	2187
4.	JG-11 (C)	45	91	42	39	53.5	0.0	490.0	25.5	2207	2187
5.	ICCV-08104	44	91	44	41	56.0	0.3	492.5	32.0	2218	2159
6.	ICCV-07103	47	93	51	47	47.0	0.8	510.0	21.3	2297	2121
7.	ICCV-08102	48	95	42	38	68.3	0.0	468.0	24.6	2108	2107
8.	ICCV-07104	45	89	50	48	56.5	0.2	497.5	21.7	2240	2055
9.	ICCV-07116	46	92	43	37	44.2	0.0	435.5	25.5	1961	1980
10.	ICCV-07112	48	94	35	33	56.5	1.4	414.8	20.5	1808	1965
11.	ICCV-08103	48	90	34	30	58.2	0.6	397.5	36.0	1790	1943
12.	ICCV-08105	46	91	40	38	34.2	0.7	426.0	33.3	1918	1917
13.	ICCV-08111	47	90	41	38	34.6	0.0	423.0	35.0	1905	1914
14.	ICCV-08106	46	90	40	33	37.0	0.0	401.0	36.0	1806	1903
15.	ICCV-07113	47	91	44	41	37.3	0.3	425.5	23.3	1916	1867
16.	ICCV-08110	46	91	35	33	27.0	0.6	389.5	32.2	1754	1860
17.	ICCV-08107	46	93	46	44	37.7	0.0	433.6	27.3	1953	1845
18.	ICCV-07111	47	93	36	32	42.1	1.0	371.0	22.5	1671	1787
19.	ICCV-07116	48	90	43	39	37.5	0.0	366.5	28.3	1650	1630
20.	Annigeri (C)	50	91	38	35	59.1	1.1	316.2	35.0	1424	1482
	Grand Mean	46	91	42	38	46.8	0.35	441.6	27.6	1987	1987
	SEm±	0.802	0.977	4.62	4.748	2.310		27.95	0.698	125.8	101.2
	CD at P≤ 0.05	1.67	2.04	NS	9.93	NS		58.49	1.46	263.2	211.81
	CV %	2.42	1.51	15.54	17.47	6.98		8.95	3.57	8.95	6.25

Date of sowing: 27-10-2008 at Nandyal Research Station, ANGARU

Source: Personal communication from Dr V Jayalakshmi

Table 6.22. Advanced chickpea yield Trial- II (Desi, Rabi 2009-10).

S.No.	Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/ Plot	Final Plant Population/ Plot	Number of Pods per plant	Pod borer (Incidence %)	100 Seed Weight (g)	Seed yield (kg/ha)
1	NBeG-49	49	82	56	55	30.6	10.22	30.5	2033
2	NBeG-165	45	84	67	63	26.6	8.49	30.0	1975
3	NBeG-43	48	84	64	60	27.0	2.96	24.8	1918
4	JG-11 (C)	46	84	55	51	34.1	2.34	24.6	1874
5	NBeG-63	45	89	44	49	23.2	8.62	37.4	1760
6	NBeG-50	50	83	63	51	28.2	5.88	30.4	1740
7	NBeG-47	45	82	58	60	22.2	2.38	36.6	1639
8	Annigeri	44	84	52	53	36.9	2.33	14.2	1621
9	NBeG-52	53	90	62	58	22.8	4.64	33.4	1601
10	NBeG-60	50	85	64	61	17.8	11.90	31.1	1593
11	NBeG-62	49	84	57	52	25.8	8.75	35.8	1586
12	NBeG-57	51	89	45	43	25.7	13.70	33.4	1582
13	NBeG-51	52	83	59	52	30.0	4.86	32.5	1562
14	NBeG-53	52	83	63	59	24.2	4.66	30.1	1312
	Grand Mean	48	85	58	55	26.8	6.45	30.3	1700
	SEm±	0.882	1.265	4.920	4.724	3.488		0.904	108.2
	CD at P≤ 0.05	2.56	3.70	NS	NS	NS		2.04	316
	CV %	3.14	2.58	14.66	14.85	22.51		5.16	11.08

Date of sowing: 10-10-2009 at Nandyal Research Station, Kurnool.

Source: Personal communication from Dr V Jayalakshmi

Table 6.23. Advanced chickpea yield Trial- I (Desi, Rabi 2010-11).											
S.No	Entry	DF	DM	I PP/ Plot	F PP/ Plot	PH	NP	PB (Incidence)	100SW	NPY	Seed Yield (kg/ha)
1	JG-11	52	90	65	62	30.5	27.7	1.7	24.5	311.4	1366.0
2	NBeG-389	51	91	62	62	30.0	30.6	3.3	22.7	306.8	1345.6
3	NBeG-390	59	103	69	66	33.1	20.4	3.7	27.4	305.1	1338.3
4	NBeG-146	53	96	68	66	30.4	25.3	4.0	27.7	298.4	1308.6
5	NBeG-147	54	97	67	65	31.1	23.3	2.5	26.4	294.5	1291.7
6	NBeG-394	54	96	70	66	31.9	29.3	3.7	30.9	293.2	1286.0
7	NBeG-393	53	95	64	60	39.3	21.3	3.2	27.0	287.6	1261.3
8	NBeG-155	52	91	68	62	32.4	24.7	1.9	29.4	284.8	1249.0
9	NBeG-156	53	95	61	54	31.9	23.9	1.3	28.7	275.2	1207.2
10	NBeG-396	54	94	62	56	29.6	22.3	2.3	29.7	272.5	1195.3
11	NBeG-397	52	91	74	69	27.3	23.5	1.3	22.4	272.3	1194.2
12	NBeG-395	53	95	73	71	31.5	24.3	2.8	27.4	269.0	1179.9
13	NBeG-388	53	96	66	63	30.0	21.4	2.5	24.5	261.1	1145.0
14	NBeG-391	60	103	71	62	32.3	20.1	3.5	26.7	245.7	1077.8
15	Annigeri	54	93	53	50	34.3	33.8	2.8	16.0	233.6	1024.4
16	NBeG-392	50	93	54	50	42.3	32.4	1.7	20.2	226.5	993.6
Grand Mean		53.6	94.92	65	61	32.4	25.28		26	277.4	1216.5
CV %		2.94	2.37	11.10	11.53	6.45	22.24		6.81	18.71	82.1
SEm±		0.91	1.30	4.20	4.09	1.21	3.25		1.01	29.96	131.4
CD at P≤ 0.05		2.63	3.75	12.12	11.81	3.48	NS		2.92	NS	0.0

Date of sowing: 27-10-2010 at Nandyal Research Station, Kurnool.

Source: Personal communication from Dr V Jayalakshmi

Table 6.24. Advanced chickpea yield Trial-II (Desi, Rabi-2011-12).										
Sl No.	Entry	DF	DM	I PP/ Plot	F PP/ Plot	PH/ Plant (cm)	NP/ Plant	100 SW (g)	NPY/ Plot (g)	Seed Yield (kg/ha)
1	JG-11	44	96	72	74	31.6	32.6	23.0	425.3	1865
2	NBeG-389	42	91	78	72	33.5	32.8	24.4	414.0	1816
3	NBeG-396	43	93	73	65	36.9	31.1	32.0	397.0	1741
4	NBeG-147	52	92	72	70	34.9	29.9	29.5	387.0	1697
5	NBeG-394	53	92	67	66	37.4	27.1	30.4	387.0	1697
6	NBeG-146	53	94	72	72	35.2	31.3	30.1	382.3	1677
7	NBeG-393	49	94	75	69	40.0	19.1	24.9	350.6	1538
8	NBeG-155	45	94	72	65	34.2	25.0	29.6	346.3	1519
9	NBeG-388	42	94	77	68	37.0	36.3	26.6	342.0	1500
10	NBeG-397	42	92	71	67	30.4	26.4	24.7	342.1	1500
11	Annigeri	42	92	77	73	37.7	50.4	15.3	339.0	1487
12	NBeG-395	50	92	75	66	34.9	28.4	28.0	326.0	1430
13	NBeG-156	45	94	78	71	36.0	26.5	29.5	325.3	1427
14	NBeG-392	40	87	78	77	43.8	26.2	20.5	308.4	1353
15	NBeG-390	62	98	74	72	37.2	26.3	29.3	263.6	1156
16	NBeG-391	62	98	75	69	37.3	22.9	29.5	208.5	914
Grand Mean		48	94	75	70	36.1	29.5	26.7	346.5	1520
SEm±		1.04	0.814	2.27	3.31	1.72	4.28	0.578	16.90	74
CD at P≤ 0.05		2.12	1.66	NS	NS	3.51	8.73	1.18	34.5	151.1
CV %		3.75	1.51	5.28	8.20	8.27	25.14	3.75	8.45	8.45

Note: Trial conducted at Nandyal Research Station, Kurnool.

Source: Personal communication from Dr V Jayalakshmi

Table 6.25. Impact of drought on chickpea yields during postrainy season, 2011-12 (kg/ha).

	JG 11			KAK 2			Vihar		
District	NY	AY	% C	NY	AY	% C	NY	AY	% C
PRM	2114	2339	11	1919	2038	6	-	-	-
KUR	1606	842*	-48	-	-	-	1591	1391	-13
ANA	1203	610*	-49	-	-	-	-	-	-
KAD	1450	1381	-5	-	-	-	1554	1969	27
NIZ	1865	1645	-12	-	-	-	-	-	-
MED	1598	1746	9	-	-	-	-	-	-
MAH	1568	165*	-89	-	-	-	-	-	-
Mean	1630	1778	9	1919	2038	6	1573	1680	7

NY: Mean normal yield based on farmer perception (kgs per ha).
AY: Mean actual yields realized during survey period, 2011-12 (kgs per ha).
% Change: Percentage change over normal yield
* severely drought affected

Table 6.25 shows the extent of damage wrought by drought on chickpea yields during the survey period 2011-12. Even though chickpea is a short-duration crop (90 days), the terminal moisture (reproductive stage) stress could cause up to 40-50% yield reductions to normal average yields. Districts such as Prakasam and Medak did not experience any drought during the postrainy cropping season. Crops in Kurnool, Anantapur and Mahabubnagar were severely damaged due to the drought; and the extent of yield losses was more significant. More pronounced yield losses (90%) were noticed in Mahabubnagar followed by Anantapur (49%) and Kurnool (48%) districts. A small influence of climate aberrations was observed in Kadapa and Nizamabad where the losses ranged from 5-10%. The extent of damage on Vihar cultivar in Kurnool district was low because of allocation of better soils and supplemental irrigation facilities. In general, farmers do better resource allocation (better land, more fertilizer and supplemental irrigation etc.) to kabuli types than desi types. The detailed yield variability analysis across study districts is also summarized in Appendix 13.

Cultivar-wise costs and returns of chickpea

Similarly, the detailed break-up of the costs of cultivation of chickpea variety-wise is presented in Appendix 14. The district-wise and cultivar-wise costs and returns per ha were analyzed and compared. A summary of this information is presented in Table 6.26. Districts such as Mahabubnagar, Anantapur and Kurnool were severely drought-affected during 2011-12 cropping year. Among the other districts, the net margins per ha are higher in Prakasam. The performance of Vihar was better in Kadapa than Kurnool district. KAK 2 was only grown in Prakasam and derived good net benefits As discussed earlier, the category-wise costs and returns from chickpea cultivation are analysed and presented in Appendix 15.

Competitiveness of chickpea with other crops

The competitiveness/substitutability of chickpea is also assessed in the sample districts and summarized in Appendix 16. A summary of this information is presented in Table 6.27. Due to the impact of drought in few sample districts in 2011-12 cropping year, the chickpea net returns were calculated using 'normalized yield levels' in those districts for comparison with other competing crops. The data clearly demonstrate the competitive edge of chickpea in the study districts over the other postrainy season crops. Farmers in the sample districts preferred chickpea because of higher returns per ha, less risk and highly suitable mechanization etc.

Table 6.26. Cultivar-wise costs and returns across sample districts (USD per ha#).

	JG 11		KAK 2		Vihar	
District name	COC/ha	GR/ha	COC/ha	GR/ha	COC/ha	GR/ha
Prakasam	1206.2	1713.5	1306.9	1733.5	-	-
Kurnool*	798.1	634.3	-	-	1052	1118.1
Anantapur*	639.0	430.6	-	-	-	-
Kadapa	795.7	1026.4	-	-	865.6	1668
Mahabubnagar*	785.1	102.4	-	-	-	-
Nizamabad	919.9	911.5	-	-	-	-
Medak	814.3	988.6	-	-	-	-

* drought-affected during 2011-12; COC: Costs of cultivation; GR: Gross Returns.
# Based on primary household survey analysis

Table 6.27. Competitiveness of chickpea across crops and districts (USD per ha#).

District	Crop	Net returns over total cost (TC)	Net returns over variable cost (VC)
Prakasam	Chickpea	458.7	1014.4
	Maize	-427.2	111.7
	Tobacco	397.5	919.6
Kurnool	Chickpea (N)	345.3	693.2
	Sorghum (N)	326.3	693.6
	Sunflower (N)	-21.6	286.0
	Coriander (N)	71.8	171.8
Anantapur	Chickpea (N)	235.8	462.3
	Sorghum (N)	-13.0	180.7
	Sunflower (N)	-291.9	-202.1
Kadapa	Chickpea	331.9	616.9
	Black gram	105.3	369.1
	Sorghum	-69.8	262.5
	Sunflower	-198.5	35.0
Mahabubnagar	Chickpea (N)	272.8	605.1
	Maize (N)	48.0	317.5
Medak	Chickpea	106.0	525.1
	Cotton	143.0	547.2
Nizamabad	Chickpea	80.3	471.6
	Sorghum	-102.0	223.6

'N' indicates returns for normal year.
Based on primary household survey analysis

6.5 Estimation of unit cost reduction from focus-group meetings

Due to peak adoption (nearly 98%) of chickpea short-duration improved cultivars in Andhra Pradesh, the primary survey could not able to capture enough 'Annigeri' growers in the study sample. The presence of 'Annigeri' was observed in selected traces of Medak and Nizamabad districts. Some of the chickpea growers in Medak combine their chickpea crop with Safflower at 9:1 ratio. Some of the chickpea households' costs and returns were not collected in the survey because of randomization of processes. Only one-third of the total samples were subjected to costs and returns information collection by plot-wise. Finally with a given probability, few plots information was only available on 'Annigeri'. This situation made us the research team to re-visit some of these sample villages and generates the estimates through focus-group meetings. For generating appropriate counter-factual at the same site and time, second round of field visits were conducted. Due to ceiling level adoption of technology, most of the sample farmers left 'Annigeri' cultivation few years back. The focus-groups were specifically designed and concentrated mostly in eliciting the expenditure pattern on JG 11 vs 'Annigeri'. The costs and returns for 'Annigeri' were collected based on their judgements 'as if they are growing Annigeri today, what kind of investments they do' and 'the corresponding plot yields based on their experience'. Thus, the focus-group results have helped the team to complement the primary household analysis as well as in estimating the UCR.

In general, most of the sample farmers agreed that they do and follow similar crop management practices between JG 11 and Annigeri cultivars. In case of Annigeri, the costs of seeds per ha would be relatively lower than JG 11. The average seed rate and corresponding price will be much lower in case of Annigeri than JG 11. The quantum of fertilizer application per ha of JG 11 will be a little higher (around 20-30 kg) than Annigeri. However, the margin of yield advantage per ha between these two cultivars was thoroughly discussed in the earlier sections (refer Table 6.19). Nearly 30-40 percent yield benefits were perceived while discussing in the FGMs and based on research station data (see Tables 6.28, 6.20 and 6.21). The item-wise costs on different operations were elicited and analysed for obtaining the unit cost of reduction (UCR) per ton when switching from Annigeri to JG 11 (see Table 6.28). The above analysis clearly revealed that the crop yields have increased from 1475 to 2017 kg per ha. The corresponding total costs[6] associated for producing them was $ 983 and $ 1054 per ha. The average cost of production per ton has come down from $ 666 to $ 522 due to increased yields of short-duration cultivars. Finally the translated unit cost reduction per ton was $ 144. In terms of rupees, UCR was estimated at Rs.7930 per ton.

6.6 Major drivers of short-duration chickpea technology adoption

The comprehensive study has facilitated the research team to identify various drivers for quick adoption of chickpea short-duration improved cultivars in Andhra Pradesh. It is worthwhile to identify and discuss those drivers upfront in the report. They are as follows:

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6. Total costs includes variable (seed, fertilizer, labor etc.) and fixed (rental value of land) costs per ha

Table 6.28. Summary of unit cost reductions due to adoption of short-duration improved cultivars ($ per ton).

Item	Prakasam (J Panguluru)				Prakasam (Parchuru)				Mahabubnagar (Manopad)				Kurnool (Uyyalawada)		Kurnool (Koilkuntla)		Guntur (Tadikonda)		Pooled	
	FGM-1		FGM-2		FGM-1		FGM-2		FGM-1		FGM-2		FGM-2		FGM-1		FGM-1			
	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11
Land preparation	99	102	94	94	103	107	117	117	67	70	90	90	72	74	67	67	79	79	88	89
Seed bed preparation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Compost/AP	0	0	0	0	0	0	0	0	0	0	0	0	22	43	0	0	0	0	2	5
Planting	46	47	45	45	38	38	43	43	27	27	27	27	27	30	27	27	40	45	36	36
Seed cost	90	138	81	121	72	105	72	112	54	111	54	92	72	97	54	90	54	90	67	106
Seed treatment	0	0	0	0	0	0	0	0	0	3	0	0	0	6	7	7	0	0	1	2
Fertilizer cost	88	98	81	90	81	82	94	94	90	97	99	108	81	87	81	85	112	126	90	96
Micro-nutrient	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interculture	0	0	0	0	0	0	0	0	0	10	0	0	0	8	0	0	0	0	0	2
Weeding	63	63	54	54	31	30	40	40	40	32	36	36	36	39	40	40	22	22	40	40
Plant protection	67	65	67	67	108	110	76	79	76	78	99	112	54	54	54	54	90	90	77	79
Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Watching	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting	67	77	63	67	72	81	72	81	54	58	45	54	49	56	49	54	63	67	59	66
Threshing	67	72	63	67	81	100	67	72	54	54	45	49	45	48	45	45	81	99	61	67
Marketing	11	14	9	9	7	8	9	11	4	9	9	9	9	18	9	13	9	13	8	12
Total-VC	598	676	557	615	593	662	591	649	467	549	503	577	467	559	433	483	550	631	529	600
Fixed cost/ha	539	539	404	404	584	584	584	584	269	269	269	269	539	539	449	449	449	449	454	454
Total cost (TC)	1137	1215	961	1019	1177	1245	1174	1233	737	818	772	847	1006	1098	882	932	999	1080	983	1054
Yield /ha (kg)	1606	2223	1482	1976	1729	2347	1853	2347	1112	1606	1173	1606	1359	1853	1235	1729	1729	2470	1475	2017
Price ($/ton)	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600
Gross Returns	876	1334	808	1186	943	1408	1010	1408	606	963	640	963	741	1112	674	1037	943	1482	805	1210
Net returns over TC	-261	119	-153	166	-234	163	-164	175	-130	145	-132	117	-265	13	-209	106	-56	402	-178	156
Net returns over VC	278	658	251	570	350	746	420	759	139	414	137	386	274	552	240	555	393	851	276	610
COP ($)	708	546	648	516	681	531	634	525	663	510	658	527	740	593	715	539	578	437	666	522
UCR per ton ($)		162		133		150		109		153		131		148		176		141		144

Note: $ US = Rs.55.

1. **Early maturing technology:** Availability of early maturing technology itself is the major driver for rapid penetration of chickpea in Andhra Pradesh. Initially, the medium duration varieties has created some scope for entry of new chickpea crop in the late 1990s in the state. After the release (in 1999) of new improved cultivar 'JG 11', there was a boom in chickpea spread in the state. The new improved cultivars has numerous advantages like high yielding, Fusarium wilt resistance, bold seeded, attractive brownish color, round and uniform size seeds etc. than earlier cultivars. This has helped the farmers to fetch higher yields (30-40%) than previous.

2. **Remunerative market prices:** India is the largest producer and consumer of chickpea in the world. In general, they consume chickpea either in whole grain, roasted split dhal, flour etc. With burgeoning population in the country, the demand for chickpea consumption increased significantly over period. During the recent time, Government of India has also increased the Minimum Support Price (MSP) for major pulses in the country to enabling pulse revolution in the country. Because of huge demand, the market prices of chickpea per unit was much higher than MSP announced by Government of India (Figure 6.14). This has motivated the farmers to quickly shift towards to chickpea from other crops. Relatively, the extent of increase in prices of chickpea competing crops was lower (Figure 6.15).

3. **Less labor intensive:** Basically, chickpea is a less labor intensive crop when compared with other competing crops in the study districts. Because of its short-duration (90 days) and suitability to mechanical cultivation led to less dependency on either family labor or hired labor for cultivation. Fig 6.16 clearly visualizes the extent of labor utilization among chickpea and its competing crops per ha.

4. **Highly suitable for mechanization:** Unlike other crops, chickpea suits well with mechanical cultivation in rainfed areas. This is clearly evident from the household data analysed for chickpea and other competing crops (Figure 6.17). Except harvesting, all other operations can be performed with machinery. Based on chickpea farmers' feedback in the survey, a farmer

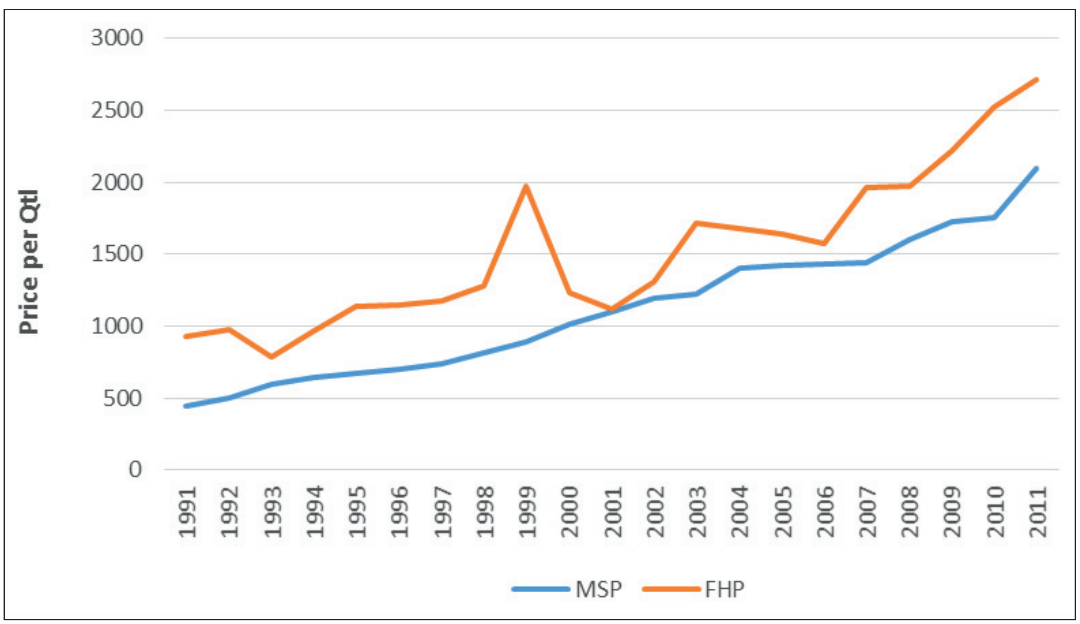

Figure 6.14. Comparative price levels of chickpea (Rs/qtl).

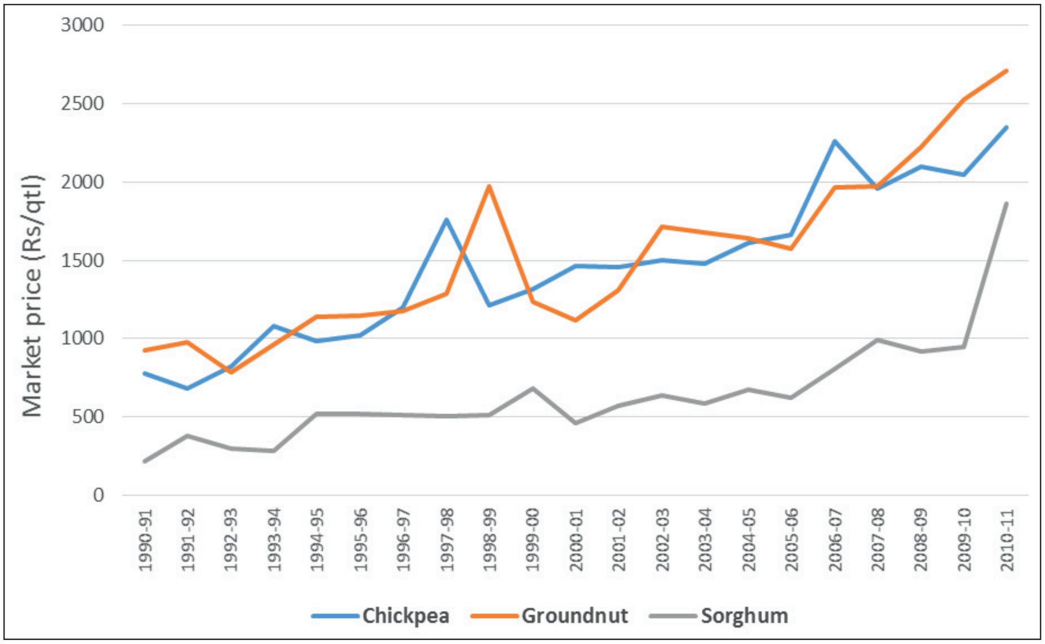

Figure 6.15. Farm harvest prices in Kurnool district, 1990-2010.

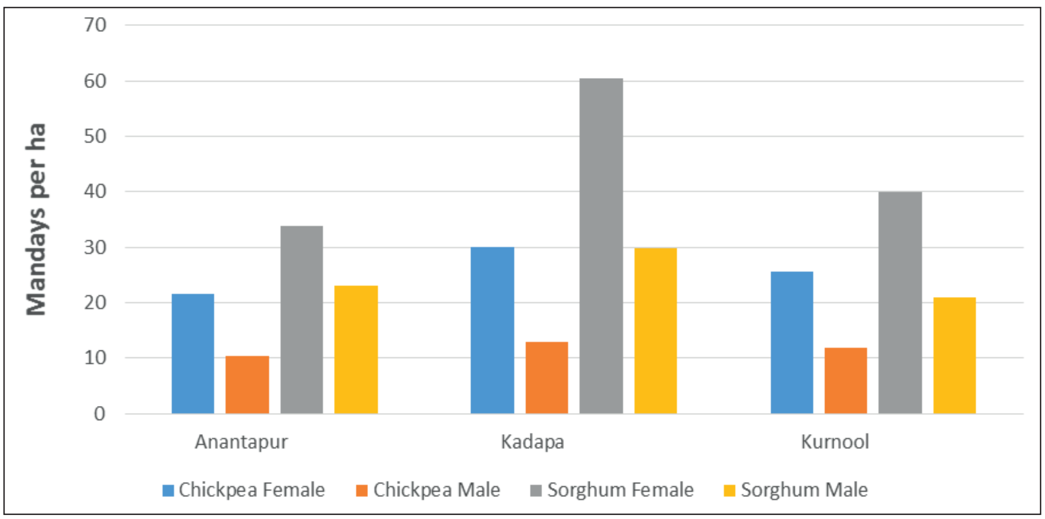

Figure 6.16. Labor utilization in chickpea vs sorghum per ha.

can cultivate up to 8 ha of chickpea with one tractor and with own family labor. With increased agricultural wage rates, farmers are preferring towards mechanization to perform timely operations in the crop.

5. **Requires low investment and less risky:** The average capital investment per ha of chickpea cultivation was relatively lower than other competing crops. Additionally, the return on investment in chickpea is more assured because of higher yields and remunerative market prices. Whereas, the capital investments in chickpea competing crops was higher (10-20%) and risky. If we compare with other commercial crops like cotton and tobacco, the average investment per ha will be nearly 30 percent higher than chickpea. It is clearly evident from primary survey data collected from chickpea growers (refer Appendix 16 for more details).

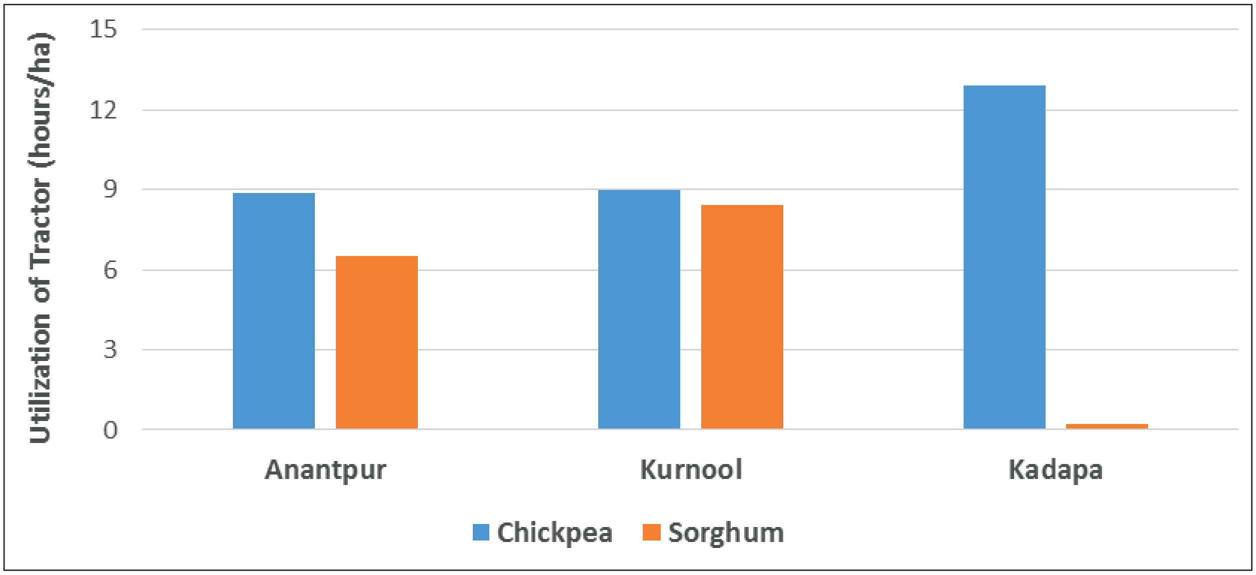

Figure 6.17. Extent of utilization of tractor (hours/ha).

7. Impact Assessment – Results and Discussion

The quantification of the welfare gains or research benefits from adoption of short-duration improved chickpea cultivars in Andhra Pradesh is estimated and presented in this section. The impact assessment analysis starts with a schematic illustration of the impact pathway for the short-duration chickpea technology (Figure 7.1). This pathway appeals to the framework illustrated (Figure 4.1) in Chapter 4 that outlines the methodology. The impact pathway uses the data and information collated from Chapters 3, 5 and 6 and demonstrates the role of critical variables in quantifying final impacts. It displays the components of the complex interactions which ultimately lead to impacts. The adaptive research infrastructure, and seeds and adoption systems are highlighted, along with the effects of new short-duration varieties on farmer's unit cost of production which enhances the chickpea market supply. It is this shift in the supply that generates welfare changes for the community, particularly the chickpea producers and consumers and the many groups ultimately influenced by the initial chickpea market changes. As explained in Chapter 4, all the minimum dataset parameters used in welfare calculations are collected from either primary household survey data or secondary sources of information. The break-up of welfare estimates is summarized and discussed in this chapter. Similarly, sensitivity analysis has also been performed to understand the extent of sensitivity of each parameter in welfare quantification process.

7.1 The Impact Pathway: ICRISAT/NARS short-duration improved chickpea varieties

The impact pathway for chickpea short-duration R4D is illustrated in Figure 7.1. The impact pathway tracks the technology development, introduction and expansion of short-duration chickpeas through ICRISAT-NARS partnerships, which produced successful varieties in 1999 and hastened adoption which ultimately resulted to the replacement of the pre-dominant old variety, Annigeri.

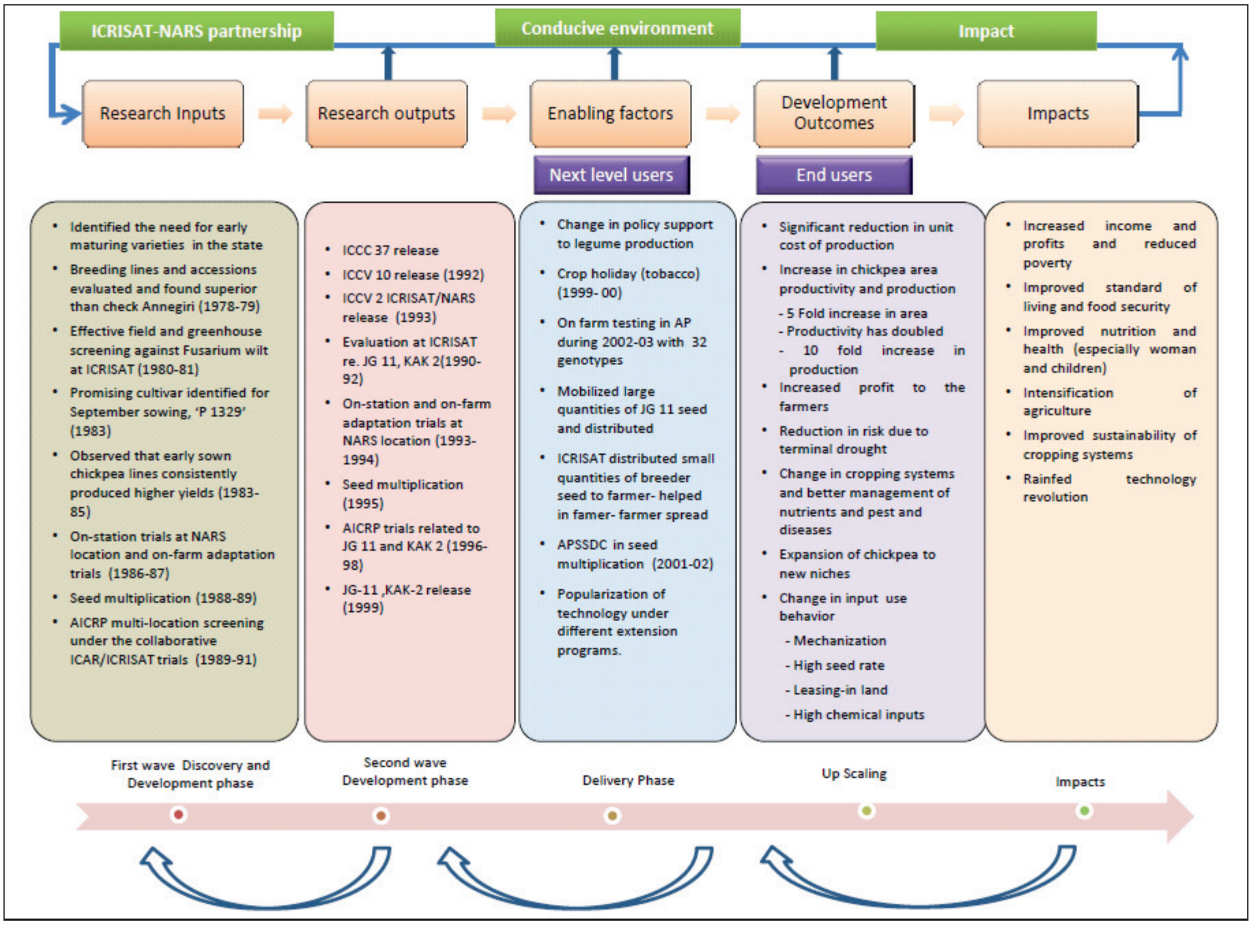

Figure 7.1. Impact pathway for short-duration chickpea research.

It demonstrates the critical engagement of stakeholders (which enabled the release, uptake and impact in Andhra Pradesh) along the R4D, extension and dissemination horizon.

It is notable that chickpea was not even a minor crop in Andhra Pradesh until 1985. While short winters, terminal moisture stress, wilt disease and pod borer were the major constraints for growing chickpea in the southern states of India, there were at least four recognized advantages in chickpea crop cultivation: easy to grow, free from foliar fungal diseases, and less vegetative growth. Farmers also perceived chickpea production to have fewer risks in production. Late maturing varieties namely Gulabi and Jyoti (selections from landraces) were under cultivation in Andhra Pradesh, alongside Annigeri which was released in 1978 from the state of Karnataka. While four more releases of medium-duration cultivars were noted including ICCC 4 and ICCV 10 in subsequent years, it was the medium-duration variety Annigeri which continued to dominate chickpea cultivation in Andhra Pradesh and the rest of southern India for more than three decades.

The schematic diagram indicates that research on short-duration cultivars started in 1978 when the initial investment of ICRISAT/NARS research inputs towards this research focus was recorded. As detailed in Chapter 3, the close and sustained collaborative efforts led to the development of the first short-duration improved chickpea cultivars Swetha (ICCV 2) and Kranthi (ICCC 37) which were released in India in 1993. But the farmers of southern India, particularly Andhra Pradesh farmers, were seemingly not ready for uptake of this new release at that time. It seems that (based on focus group meeting with farmers and personal communication with concerned breeders) this first short-duration release was considered to be too extra early maturing. Also relevant was the constrained seed multiplication encountered and therefore limitations in seed availability. In other words, this release in 1993 did not have a successful uptake. While other short-duration varieties were also released during the mid-90s, all faced similar constraints as well.

The continuing research collaboration between ICRISAT with Jawaharlal Nehru Krishi Vishwavidyalaya (JNKVV), Jabalpur, and Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, on crop improvement and management addressed more aggressively the above constraints and harnessed opportunities to develop new cultivars which could make chickpea a most suitable crop for the region. A network programme from ICRISAT with south and central zone research stations was initiated through exchange of breeding material with an aim of identifying short-duration, high-yielding and disease-resistant varieties. This led to the development of a second wave of releases starting 1999 including desi type cultivars (JG 11, JAKI 9218, SAKI Nandyal-1) as well as kabuli types (KAK 2, VIHAR, JKG 1). To follow this up, on-farm trials which were conducted in early 2000 strongly recommended the adoption of short-duration and high-yielding varieties, specifically JG 11 and KAK 2. Since then Andhra Pradesh witnessed a notable uptake of improved chickpea cultivars and corresponding increase in cropped area.

The joint partnerships that successfully released and promoted the second wave of short-duration chickpea releases, particularly JG 11 and KAK 2 among others, seemed to have come at exactly the right time given the context of the crop production and economic environment surrounding chickpea around 1999. Interviews with farmers and focus group meetings revealed that Andhra Pradesh farmers in the late 1990s to early 2000s were particularly looking for alternative more remunerable crop options to substitute for the traditional crops like tobacco, sunflower and sorghum; and they especially recognised that chickpea fetched good market prices. Notably it was also in the late 90s that the Government of Andhra Pradesh declared a ‘tobacco holiday’ which banned or discouraged tobacco production for one year due to unfavourable global export markets. But most critically, the driving factor that enabled the fast uptake process was the research, extension and seed multiplication agencies in Andhra Pradesh actively joining with ICRISAT and JNKVV, Jabalpur, to address the binding seed constraint experienced during earlier years. Specifically, the bulk introduction and multiplication of seed by Andhra Pradesh State Seed Development Corporation (APSSDC) were complemented by the Department of Agriculture subsidy which enabled distribution of huge quantities of improved seeds to farmers. This joint massive collective effort not only made farmers aware of the new releases but enabled them to have access to improved seeds as farmers increasingly found chickpea to be more remunerative compared to the old chickpea variety Annigeri and even more competitive than other traditional crops grown in the rainfed regions of the state.

By and large, the impact pathway highlights the Andhra Pradesh farmers’ hastened uptake of JG 11 and KAK 2 (among the second wave releases of short-duration chickpea varieties technology) as the R4D effort of ICRISAT and national program partners were significantly complemented with enabling seed systems infrastructure and conducive economic and policy environment, all of which were instrumental in up-scaling the chickpea technology towards creating a real legumes revolution in Andhra Pradesh. Approaching the year 2010, the hitherto predominant variety Annigeri (and other traditional crops including tobacco, sorghum, sunflower etc.) have been replaced by improved short-duration cultivars. This resulted in what is now referred to as the 'silent chickpea revolution' with five-fold increase in area, doubled productivity and ten-fold increase in production in the state. Currently, more than 90 percent of chickpea area in the state is covered with short-duration chickpea cultivars (especially JG 11 and KAK 2) and most of farmers have moved from subsistence to commercial chickpea farming by mechanizing their operations except harvesting.

The impact analysis and measurement in subsequent sections will show how JG 11 and KAK 2 (among the second wave release of short-duration cultivars) which produced significantly higher yields and lower unit cost of production (and therefore higher profits) have ultimately achieved measurable impacts with widespread welfare gains to both chickpea producers and consumers of Andhra Pradesh in India.

7.2 Key parameters used in welfare estimation calculations

The robustness of welfare estimates for any technology lies in usage of proper or most reliable key parameters. The minimum dataset parameters should be properly assessed and validated through a rigorous process. Any error in the estimation or usage of improper parameters can lead to unrealistic estimation of welfare benefits. So enough care has been taken in assessing the following key parameters:

1. ***Base level of annual production:*** The base level of annual production of chickpea used for chickpea short-duration improved cultivars are 2011-12 data generated by both Directorate of Economics and Statistics, Andhra Pradesh (at sub-national level) and Department of Agriculture and Cooperation, New Delhi (at national level). Since the technology adoption is in its peak stage in Andhra Pradesh (around 98 percent) during the survey reference year, we have used this base level production data for welfare estimate calculations. However, the analysis of this time series data have extensively discussed in Chapter 3.

2. ***Elasticity's:*** The demand and supply elasticity values used for the chickpea welfare estimations were adopted from earlier ICRISAT research studies. The important result of disaggregation which started with just having multiple countries in the early ACIAR analysis is that the welfare estimates and even their distribution between different groups become much less sensitive to supply and demand elasticities than with an aggregate analysis. This surprises many but when the analysis is dissected in more detail what becomes clear is that it is the share of total production by each group and associated spillovers/applicability which become the overriding parameters which drive the distributive effects not the elasticities. This means that using different elasticity estimates for each disaggregated group does not make very much difference to the total but even distribution of the benefits.

3. ***Unit cost reduction (UCR):*** The details of adoption of short-duration improved cultivars and the corresponding unit cost reduction was estimated and presented in Table 6.28.

4. ***Adoption:*** The research and adoption lags were estimated with through discussions with ICRISAT chickpea breeders and other experts from Andhra Pradesh. ICRISAT has started the research for development of short-duration cultivars in early 1980s. The first batch of cultivars has been released in early 1990s but did not accept by farmers due to various reasons. The second batch

of releases happened during 1999 which liked by farmers very much. Nearly, 22 years (from 1978 to 1999) of research lag was estimated for this study. After formal release of these cultivars, the seed multiplication and subsequent adoption taken little more time to reach the ceiling level of adoption in the state. Different sample districts taken diverse adoption pathways to reach the peak level adoption by 2012. The initial adoption lag ranged from 3 to 8 year across sample districts of AP. However, the total time taken from start of the project to reach the ceiling level of adoption was ranged between 35 to 41 years in case of Andhra Pradesh (also see Table 7.1 and 7.2). For estimating the welfare benefits beyond AP, the key parameter assumed beyond AP are summarized in Table 7.3.

5. ***Discount rates:*** 5 percent discount rate was used in the welfare estimates calculation.

6. ***Exchange rates:*** Rs.55 per US dollar exchange rate was used for all necessary conversions in the report.

7. ***Research costs:*** The costs incurred by both ICRISAT and NARS for short-duration cultivar development and extension costs were estimated and used in the welfare calculations. The detailed break-up of the same is summarized in Chapter 3 from 1978 to 2013 (also see Table 3.9).

8. ***Estimation of BCR and IRR:*** The research benefits accruing over a period (1978-2037) and costs incurred in the developing the technology and extension (1978-2013) were discounted and calculated the Net Present Value (NPV) from those differences between them. Similarly, the Benefits-Cost Ratio (BCR) and Internal Rate of Return (IRR) were estimated and summarized in this section.

Table 7.1. Summary of key parameter estimates for assessing welfare gains-Andhra Pradesh (Part A).

Parameter	PRM	KUR	ANA	KAD	MED	NIZ	MAH	Rest of AP	Rest of India
Start of project: 1978; Date of completion: 1999									
Start of adoption (addl. years seed multiplication)	2002	2001	2002	2003	2007	2007	2003	2003	2003
Year ceiling level of adoption was reached	2012	2012	2012	2012	2012	2012	2012	2018	2018
Unit cost reduction ($/ton)	144	144	144	144	144	144	144	144	-

Table 7.2. Summary of key parameter estimates for assessing welfare gains – Andhra Pradesh (Part B).

Parameter	PRM	KUR	ANA	KAD	MED	NIZ	MAH	Rest of AP	Rest of India
Chickpea production ('000 tons)	150.0	310.0	83.0	61.0	44.0	52.0	38.7	71.3	5727
Chickpea consumption ('000 tons)	20.7	42.8	11.5	8.4	6.1	7.2	5.3	9.8	8239
Farm gate price ($/ton)[#]	651	651	651	651	651	651	651	651	651
Elasticity of supply	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Elasticity of demand	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Research lag (years)	22	22	22	22	22	22	22	22	22
Years from start of the project to start of the adoption (years)*	25	24	25	26	30	30	26	26	26
Initial adoption lag (years)**	3	2	3	4	8	8	4	4	4
Years from start of the project to maximum adoption (years)	35	35	35	35	35	35	35	41	41
Maximum adoption (proportion)	1	1	1	1	1	1	1	1	-
Unit cost reduction ($/ton)	144	144	144	144	144	144	144	144	-

Estimates based on survey results, FGDs and secondary data.

* ICRISAT started research on short-duration cultivars in 1978 (Improved cultivars were released in 1999).

** From release of cultivars to initial adoption.

\# Based on Andhra Pradesh Agricultural Statistics, 2012.

Table 7.3. Summary of key parameter estimates for assessing welfare gains (Beyond AP).

Parameter	Karnataka	Maharashtra
Chickpea Production ('000' tons)	573	1100
Chickpea consumption ('000' tons)	429	784
Farm gate price ($/ton)#	651	651
Elasticity of supply	0.9	0.9
Elasticity of demand	0.6	0.6
Research lag (years)	22	22
Years from start of the project to start of the adoption (years)*	26	26
Initial adoption lag (years)**	4	4
Years from start of the project to maximum adoption (years)	41	41
Maximum adoption (Proportion)	1	1
Unit cost reduction ($/ton)+	80	80

Estimates based on survey results, FGDs and secondary data.

* ICRISAT started research on short duration cultivars since 1978 (Improved cultivars released in 1999 & 2000)

* * From release of cultivars to initial adoption

\# Based on Andhra Pradesh Agricultural Statistics, 2012

\+ Estimated based on Tropical Legumes II (TL II) and VLS project studies

7.3 Estimation of direct welfare benefits to Andhra Pradesh

Based on the principle of economic surplus, the direct welfare benefits to Andhra Pradesh are estimated and presented in Table 7.4. The minimum dataset parameters used for generation of these benefits were summarized in Tables 7.1 and 7.2. Based on the estimated average UCR of $144 per ton, the direct welfare benefits to Andhra Pradesh due to adoption of short-duration cultivars was $358.9 million. Producers received more benefits than the consumers because Andhra Pradesh exports most of its chickpea to the rest of India, especially northern India. In a most conservative scenario, the benefits are estimated to fall to $284.2 million if variations in yields across different eco-systems are included. Although, under the most optimistic conditions – higher ceiling levels of adoption – the total benefits were estimated to be $429.8 million over the estimated period ie, 1978 to 2037. Farmers who adopted the short-duration improved cultivars are found to receive the principal share of benefits. These large welfare gains were made possible through strong partnerships between ICRISAT and NARS coupled with policy support from the Government of Andhra Pradesh.

Table 7.4. Direct welfare gains due to adoption of short-duration improved cultivars in Andhra Pradesh (US$ millions).

Type	S1: Conservative scenario (UCR=$117/ton)	S2: Business as usual scenario (UCR=$144/ton)	S3: Optimistic scenario (UCR=$169/ton)
Total chickpea production ('000 m tons)	810.0	810.0	810.0
Total chickpea consumption ('000 m tons)	111.8	111.8	111.8
Total welfare change#	284.2	358.9	429.8
Producer surplus#	279.3	353.3	423.7
Consumer surplus#	5.0	5.6	6.1
Adopters benefits#	284.1	358.7	429.7
Non-adopters#	-4.9	-5.4	-5.9

UCR = Unit Cost Reduction; # = Million dollars

Dis-aggregated UCR and welfare benefits

The welfare benefits accrued to Andhra Pradesh using the dis-aggregated UCRs across production environments (PEs) are summarized in Table 7.5. In general, the normal aggregate estimates masks the range of important implications of research impacts by hiding the exceeded welfare gains of favourable environments with that of lower benefits to the non-favourable environments. There is an equal chance of committing significant empirical error in over or under measuring the welfare changes by ignoring the different production environments. The detailed understanding of different production environments and technology adoption process facilitates incorporation of each component of the story/activity in its appropriate form rather than developing an additional set of hypothetical assumptions. The total welfare benefits for Andhra Pradesh have increased marginally (8%) when we used dis-aggregated UCRs than the aggregated UCR (144 $/ton). This clearly reflects the underestimation of total welfare benefits due to short-duration improved cultivars in Andhra

Pradesh. This empirical exercise clearly reveals that the UCR estimations will not be same across different production environments (PEs) as we perceive normally[7]. For increasing the precision in estimates of welfare benefits, it would always be better if we use the dis-aggregated UCR across PEs.

Table 7.5. Welfare benefit estimates for Andhra Pradesh using dis-aggregated UCR (US$ millions).

Type	S1: Dis-aggregated UCR*	S2: Aggregated UCR
Total chickpea production ('000' m tons)	810.0	810.0
Total chickpea consumption ('000' m tons)	111.8	111.8
Total welfare change #	388.4	358.9
Producer surplus #	382.6	353.3
Consumer surplus#	5.8	5.6
Adopters benefits #	388.2	358.7
Non-adopters #	-5.6	-5.4

UCR: Unit Cost Reduction # Million dollars
* Actual UCRs estimated across study districts used.

Welfare benefits across major districts of AP

Due to the disaggregation in the analysis the aggregate welfare benefits for Andhra Pradesh can be separated to illustrate the extent of benefits accruing to various study districts in the state. For deeper understanding, the detailed break-up of welfare benefits across the sample districts are summarized in Table 7.6 using the most likely scenario. Nearly 47 percent of the total Andhra Pradesh benefits accrue to the Kurnool district, followed by Prakasam, Anantapur and Kadapa. The rest of Andhra Pradesh does not benefit because of very low levels of adoption beyond the seven districts included in the study. It is noted that the non-adopters of short-duration chickpea technology in Medak and Nizamabad have measurable welfare losses due to the price reducing effect of the increased production.

Table 7.6. Break-up of welfare benefits across major districts of AP (in million $).

Type	AP Total	KUR	PRM	ANA	KAD	MAHA	NIZ	MED	Rest of AP
Total research benefits	358.9	167.5	77.8	43.5	30.7	19.5	11.8	8.5	-0.4
Producer gain	353.3	165.3	76.8	42.9	30.3	19.2	11.5	8.2	-0.9
Consumers gain	5.6	2.1	1.0	0.6	0.4	0.3	0.4	0.3	0.5
Adopters benefits	358.7	165.4	76.8	42.9	30.3	19.2	12.6	9.3	2.2
Non-adopters losses	-5.4	-0.1	0.0	0.0	0.0	0.0	-1.1	-1.1	-3.1

Million dollars

[7] Check http://ageconsearch.umn.edu/bitstream/165847/2/KumaraCharyulu%20CP.pdf for more details.

Welfare benefits by category of farmers in AP

As was explained in Chapter 4 and 5 (see Appendix 15) of this report, the silent rainfed chickpea revolution in Andhra Pradesh happened because of rapid uptake of short-duration improved cultivars by farmers in a short span of time. The deeper secondary analysis of chickpea data and research process clearly convince us that the steep rise in chickpea production in Andhra Pradesh was achieved due to the adoption and changed behaviour of two types of farmers: 1. Traditional chickpea growers who replaced Annigeri with JG 11 and other improved cultivars; and 2. Non-chickpea growers who shifted from other non-chickpea traditional crops grown in rainfed regions to chickpea cultivation (switchers). The aggregate total welfare estimates for Andhra Pradesh mask or hide the significance of this story. The disaggregation or relative break-up of these benefits under the most likely scenario is presented in Table 7.7. Nearly 68 percent of total welfare benefits in AP were due to switcher farmers who moved from non-chickpea to chickpea cultivation. A significant share of almost $120 m total benefits accrued to traditional chickpea growers who replaced Annigeri with the improved short-duration cultivars.

Table 7.7. Welfare benefits by category of farmers.

			Adopters	
Type	Total AP benefits	Benefits due to non-adopters	Benefits due to traditional growers	Benefits due to switcher farmers
Total welfare change#	358.9	-4.6	119.5	244.0
Producer surplus #	353.3	-5.4	118.0	240.8
Consumer surplus#	5.6	0.8	1.6	3.2

= Million dollars

7.4 Estimation of total welfare gains to India

The diffusion of short-duration chickpea cultivars are slowly spreading beyond Andhra Pradesh borders to the neighbouring vertisol areas of Karnataka and southern Maharashtra. As we pointed out in Appendix 2 (see Figure 3.2), the short-duration cultivars have strong research applicability in these neighbouring states. However, the institutional constraints and lack of conducive policy support plays a significant role in determining the extent of adoption and therefore research benefits in these states. ICRISAT, in collaboration with NARS partners from fours states of India, were involved in the development of these short-duration cultivars. The present study made an attempt to quantify those research benefits beyond Andhra Pradesh. The total accrued benefits for all India (including Andhra Pradesh) are summarized in Table 7.8. Note that in calculating the research benefits to India, only the short-duration research domains were considered. Consumers are noted to be deriving larger benefits than producers due to the benefits derived from lower prices of chickpea. Non-adopters are shown to be losing a huge share of research benefits.

Table 7.8. Direct welfare benefits to India due to short-duration cultivars (US$ millions).	
Type	Total benefits to India*
Total chickpea produced ('000 m tons)	8210.0
Total chickpea consumed ('000 m tons)	9563.8
Total welfare change#	543.9
Producer surplus#	83.7
Consumer surplus#	460.2
Adopters benefits#	425.3
Non-adopters#	-341.6

#= Million dollars; *for short-duration environment only

7.5 Flow of net research benefits due to adoption of short-duration cultivars

The annual flow of research costs and research benefits provide a deeper understanding about welfare gains due to short-duration chickpea improved cultivars in India. The research and development costs including the extension costs of ICRISAT and NARS were considered from 1978 to 2013 for calculation of project costs (see Table 3.9). The research benefits gained each year from 1978 to 2037 (60 years) were taken into consideration for calculation of the project's net present value of the benefits and internal rate of returns on research investments. The summary of the flow of project research costs and benefits is shown in Table 7.9. The flow of costs and benefits was discounted with five percent discount rate for the project period. The resulting net present value (NPV) was calculated by taking the differences between total discounted costs and discounted research benefits. Similarly, the project benefit-cost-ratio (BCR) and internal rate of returns were also estimated and presented in Table 7.10.

Table 7.9. Flow of research costs and benefits (US$).

Year	Costs	Research benefits to India (including AP)	Net benefits	Discounted net benefits
1978	108,411	-	-108,411	($103,248)
1979	108,411	-	-108,411	($98,332)
1980	108,411	-	-108,411	($93,649)
1981	108,411	-	-108,411	($89,190)
1982	108,411	-	-108,411	($84,943)
1983	108,411	-	-108,411	($80,898)
1984	108,411	-	-108,411	($77,046)
1985	109,210	-	-109,210	($73,918)
1986	94,488	-	-94,488	($60,908)
1987	86,087	-	-86,087	($52,850)
1988	79,922	-	-79,922	($46,729)

Continued

Table 7.9. *continued*

Year	Costs	Research benefits to India (including AP)	Net benefits	Discounted net benefits
1989	79,393	-	-79,393	($44,209)
1990	174,689	-	-174,689	($92,641)
1991	170,722	-	-170,722	($86,226)
1992	165,637	-	-165,637	($79,674)
1993	170,597	-	-170,597	($78,152)
1994	170,181	-	-170,181	($74,249)
1995	155,167	-	-155,167	($64,475)
1996	159,643	-	-159,643	($63,176)
1997	169,897	9,986	-159,910	($60,269)
1998	177,684	174,873	-2,811	($1,009)
1999	181,413	339,973	158,560	$54,204
2000	341,621	535,030	193,408	$62,968
2001	359,055	1155,827	796,772	$247,053
2002	361,051	3,650,307	3,289,256	$971,327
2003	338,277	10,175,651	9,837,374	$2,766,670
2004	314,441	21,931,921	21,617,479	$5,790,206
2005	305,618	35,191,342	34,885,724	$8,899,126
2006	298,805	48,648,052	48,349,247	$11,746,272
2007	437,501	62,368,720	61,931,219	$14,329,487
2008	404,046	77,575,183	77,171,137	$17,005,391
2009	432,249	93,317,794	92,885,545	$19,493,533
2010	555,123	10,9293,141	108,738,018	$21,733,744
2011	505,827	125,054,288	125,018,460	$23,797,864
2012	515,871	141,758,895	141,243,024	$25,605,988
2013	513,760	143,914,536	143,400,776	$24,759,207
2014		146,083,109	146,083,109	$24,021,268
2015	-	148,204,080	148,204,080	$23,209,554
2016	-	150,337,975	150,337,975	$22,422,603
2017	-	152,484,793	152,484,793	$21,659,806
2018	-	154,644,534	154,644,534	$20,920,560
2019	-	154,666,150	154,666,150	$19,927,128
2020	-	154,687,768	154,687,768	$18,980,870

continued

Table 7.9. *continued*				
Year	Costs	Research benefits to India (including AP)	Net benefits	Discounted net benefits
2021	-	154,687,768	154,687,768	$18,077,019
2022	-	154,687,768	154,687,768	$17,216,209
2023	-	154,687,768	154,687,768	$16,396,389
2024	-	154,687,768	154,687,768	$15,615,609
2025	-	154,687,768	154,687,768	$14,872,008
2026	-	154,687,768	154,687,768	$14,163,817
2027	-	154,687,768	154,687,768	$13,489,350
2028	-	154,687,768	154,687,768	$12,847,000
2029	-	154,687,768	154,687,768	$12,235,238
2030	-	154,687,768	154,687,768	$11,652,608
2031	-	154,687,768	154,687,768	$11,097,722
2032	-	154,687,768	154,687,768	$10,569,259
2033	-	154,687,768	154,687,768	$10,065,961
2034	-	154,687,768	154,687,768	$9,586,629
2035	-	154,687,768	154,687,768	$9,130,123
2036	-	154,687,768	154,687,768	$8,695,355
2037	-	154,687,768	154,687,768	$8,281,291
Total	8,586,850	4,566,365,991	4,557,779,141	540,890,627
NPV value*	2,963,872	543,854,499	540,890,627	

* at 5 percent discount rate

Table 7.10. Short-duration chickpea cultivars impact evaluation indicators for India.

Item	Indicator value
Discounted total flow of costs#	2.96
Discounted total flow of benefits#	543.85
Net present value (NPV)#	540.89
Benefit-cost-ratio (BCR)	183.5
Internal rate of returns (IRR)	28%
Modified Internal rate of returns (MIRR) @ 30 percent	27%

= US million dollars

The total discounted project cost is estimated at $2.96 million, while the discounted welfare benefits are estimated at $543.85 million. Therefore, the net present value of $540.89 million was achieved. The investment of each dollar in the project earned 183.5 dollars over the period of time. This is translated to an internal rate of research investments of 28 percent. Figure 7.2 presents the flow of net benefits derived over the horizon of 60 years.

7.6 Sensitivity analysis of welfare benefits (with reference to Andhra Pradesh only)

The exercise on sensitivity of welfare benefits in Andhra Pradesh was done and presented in Tables 7.11a to 7.11e. This exercise clarified that the results are more sensitive to yield variations due to drought/climate aberrations. Changes in farm gate prices per ton did not have significant implications of the extent of derived welfare benefits. However, the change in research lags, adoption lags and unit cost reductions (UCR) show significant implications on the magnitude of the research benefits accruing over a period of time. The following five scenarios specifically for Andhra Pradesh were undertaken and their corresponding research results are summarized below:

1. Impact of drought on productivity

The impact of drought has significant influence on the welfare gains from short-duration chickpea in Andhra Pradesh. The deviation in crop yields per ha has direct influence on unit cost reduction (see Table 7.11a). A 10% deviation in normal yield per ha has considerably reduced welfare gains for AP (by around 150 million) as this translated to almost 40% decline in unit cost reduction (UCR). Similarly, a 20 percent reduction in normal yield per ha brought almost negligible research benefits (with 90% reduction in UCR). Any further reduction in crop yields (> 25 percent than normal) generates welfare losses to the state. These results give an imperative high importance in the crop improvement for generating drought tolerant cultivars for reaping higher research benefits or minimizing welfare loss.

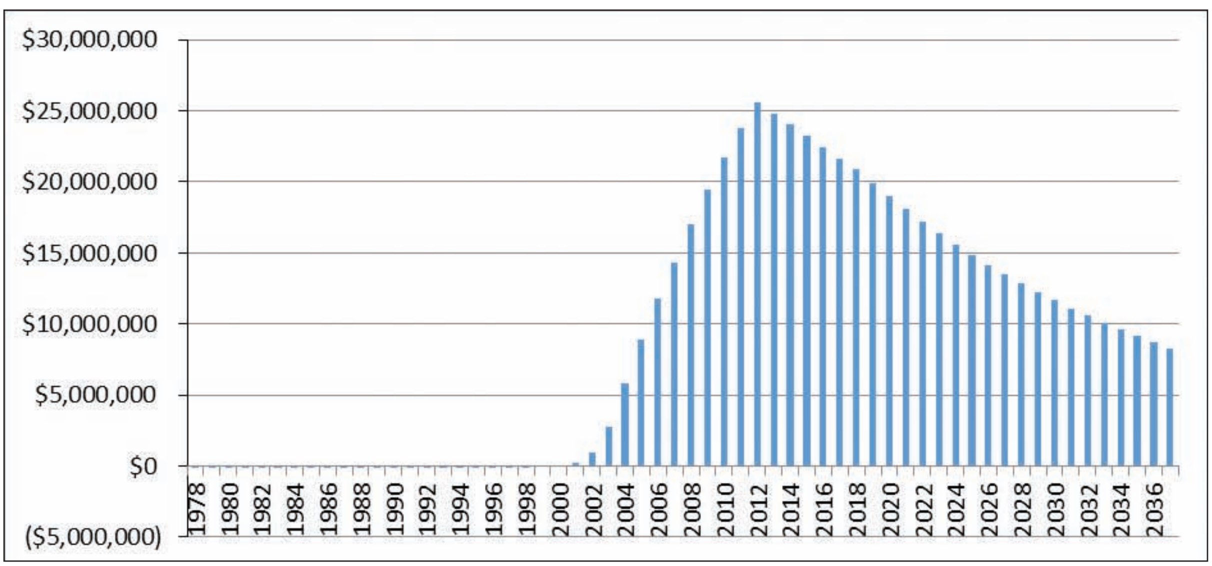

Figure 7.2. Flow of discounted net benefits over the project period (US $).

Table 7.11a. Influence of drought on chickpea crop yields.			
S1: UCR $144/ton @ chickpea productivity at 1975 kg per ha S2: UCR $117/ton @ chickpea productivity at 1777 kg per ha (10% reduction) S3: UCR $86/ton @ chickpea productivity at 1580 kg per ha (20% reduction)			
Type	S1: Business as usual scenario (UCR = $144/ton)	S2: 10% reduction in yield (UCR = $86/ton)	S3: 20% reduction in yield (UCR = $14/ton)
Total chickpea produced ('000 m tons)	810	810	810
Total chickpea consumed ('000 m tons)	111.8	111.8	111.8
Total welfare change#	358.9	201.1	18.7
Producer surplus#	353.3	196.8	15.9
Consumer surplus#	5.6	4.3	2.8
Adopters benefits#	358.7	201.1	18.7
Non-adopters # -5.4		-4.2	-2.8

UCR: Unit Cost Reduction; # = Million dollars

2. Changes in farm gate prices due to increase in imports (as experienced by Andhra Pradesh in Sept 2013)

The influence of farm gate prices on the chickpea welfare estimates is summarized in Table 7.11b. The deviations in farm gate prices per ton did not have significant influences on the derived welfare gains in Andhra Pradesh. Due to changes in the international market, countries like Canada, Australia and Iran are already exporting large quantities of kabuli types of chickpeas into India. This exporting definitely reduces the farm gate prices per ton and also weakens the market demand of local chickpeas grown within the country. However, India being the largest producer and consumer of chickpea in the world, the total welfare is not changing much.

Table 7.11b. Change in farm gate price ($/ton) due to measurable increase in imports.				
S1: Farm gate price @ $651 per ton (Business as usual) S2: 5% decrease in farm gate price @ $618 per ton S3: 10% decrease in farm gate price @ $586 per ton S4: 15% decrease in farm gate price @ $553 per ton				
Type	S1: Farm gate price @ $651/ton	S2: Farm gate price @ $618/ton	S3: Farm gate price @ $586/ton	S4: Farm gate price @ $553/ton
Total chickpea produced ('000 m tons)	810	810	810	810
Total chickpea consumed ('000 m tons)	111.8	111.8	111.8	111.8
Total welfare change#	358.9	359.4	360.0	360.6
Producer surplus#	353.3	353.7	354.1	354.6
Consumer surplus#	5.6	5.7	5.9	6.0
Adopters benefits#	358.7	359.2	359.8	360.4
Non-adopters#	-5.4	-5.5	-5.7	-5.8

UCR = Unit Cost Reduction; # = Million dollars

3. Change in ceiling level of adoption lag

Research and adoption lags are sensitive parameters in the welfare benefits calculations for any technology. In case of chickpea in Andhra Pradesh, the short-duration cultivar development research was initiated at ICRISAT in early 1978 and successful cultivars were released since 1999. This is 22 years of research lag, and an additional 13 years took place from formal release of the cultivars to reach ceiling level of adoption. Any advance of adoption lag (say five years) would enhance the research benefits (nearly $60 million) in shorter period of time (see Table 7.11c). However, Tropical Legumes Project-II supported by the Bill and Melinda Gates Foundation (BMGF) has targeted accelerating the adoption process in AP since 2008 through conducting Farmers' Participatory Varietal Selection (FPVS) trials, seed samples distribution and other mass media communications. The adoption reached its peak in 2012 due to project intervention activities in Andhra Pradesh. In the absence of this project, it is expected that it would have been taken another 3-5 years to reach the ceiling level of adoption in the state. By reducing the ceiling level of adoption from 40 to 35 years, Andhra Pradesh chickpea farmers have accrued almost $60 million ($307.7 m to $358.9 m).

Table 7.11c. Change in ceiling level of adoption lag (years).

S1: Business as usual scenario – ceiling level of adoption lag is 35 years, ie, 2012
S2: Advancing the ceiling level of adoption lag to 30 years ie, 2007
S3: Absence of TL-II project interventions: adoption lag might be extended up to 40 years

Type	S1: Ceiling adoption @ 35 years	S2: Ceiling adoption @ 30 years	S3: Ceiling adoption @ 40 years
Total chickpea produced ('000 m tons)	810	810	810
Total chickpea consumed ('000 m tons)	111.8	111.8	111.8
Total welfare change#	358.9	419.0	307.7
Producer surplus#	353.3	413.0	302.5
Consumer surplus#	5.6	6.0	5.1
Adopters benefits#	358.7	418.9	307.5
Non-adopters#	-5.4	-5.9	-5.0

UCR = Unit Cost Reduction; # = Million dollars

4. Unit cost reduction across study districts

Other most important parameter in technology assessment and research welfare estimates is unit cost reduction (UCR). Due to enhancement of yield with new technology or saving the losses due to resistant cultivars reduces per unit cost of production and ultimately brings welfare benefits to the farmer. Similarly, any changes in crop management and its associated environmental conditions exhibit in terms of variability in productivity. Among the seven sample districts; Prakasam, Kadapa, Nizamabad and Medak districts have better rainfall regimes and soils. But, districts like Anantapur, Mahabubnagar and Kurnool receives low rainfall and having poor soils. The UCR calculations across seven districts showed a range from 131 to 176 $ per ton. These differences in UCR among study districts bring huge variability in welfare calculations (see Table 7.11d).

Table 7.11d. Ranges in UCR across favourable and un-favourable environment districts.			
S1: Business as usual scenario (Mean UCR @ $144 per ton) S2: District with unfavourable environment (UCR @ $131 per ton) S3: District with favourable environment (UCR @ $176 per ton)			
Type	S1: Mean UCR @ $144/ton	S2: Unfavourable environment UCR @ $131/ton	S3: Favourable environment UCR @ $176/ton
Total chickpea produced ('000 m tons)	810	810	810
Total chickpea consumed ('000 m tons)	111.8	111.8	111.8
Total welfare change#	358.9	322.7	450.0
Producer surplus#	353.3	317.4	443.8
Consumer surplus#	5.6	5.3	6.3
Adopters benefits#	358.7	322.6	449.8
Non-adopters#	-5.4	-5.1	-6.1

UCR = Unit Cost Reduction; # = Million dollars

5. Further diffusion of chickpea in Andhra Pradesh

The spatial analysis undertaken in Chapter 2 demonstrated that the scope for further expansion of chickpea production in Andhra Pradesh is likely to be limited to the remaining rainfed niches in the vertisol regions of Adilabad in north-western AP. Determination of the possible extent of area expansion has been achieved by re-examining some more details of the chickpea research domains defined in Chapter 2. For example, the research domain for chickpea production has been delineated by five variables: rainfall, temperature, soil type, latitude, and length of growing period. Consideration of one additional variable, ie, irrigation, has been shown to be critical in delineating likely areas of expansion as well as the likely influences on crop suitability and competitiveness of chickpea production vis-à-vis other cropping system options. While irrigation has not been taken into account in the initial spatial analysis of the research domain, the analysis of chickpea illustrated that it may indeed be an important factor influencing the suitability of chickpea and therefore the expansion of chickpea area and production. The conclusions drawn from the spatial analysis in Chapter 2 indicate a high probability scenario representing a specific situation where the district of Adilabad (which is currently classified under "rest of AP") could double its chickpea production from the current level of 71,300 tons. This scenario considers that the increase in production is due to farmers adopting new improved varieties (JG 11, Vihar and/or KAK 2) or farmers switching from non-chickpea crops. Thus, this scenario presents the likely additional benefits if indeed this expansion occurs in the remaining rainfed vertisols of Andhra Pradesh including the district of Adilabad. This will add an estimated research benefits of $ 11 million to the existing 'baseline' scenario (see Table 7.11e).

Table 7.11e. Ceiling level of chickpea adoption has not been reached and continues to expand further to other districts.

S1: Business as usual scenario: UCR $144/ton and ceiling adoption of 7.5% by 2018

S2: Expansion of area, particularly in Adilabad ceiling adoption of 37 % by 2015

Type	S1: Business as usual scenario (UCR = $144/ton)	S2: Expansion to Adilabad with 37% adoption by 2015
Total chickpea produced (’000 m tons)	810	810
Total chickpea consumed (’000 m tons)	111.8	111.8
Total welfare change#	358.9	369.6
Producer surplus#	353.3	364.0
Consumer surplus#	5.6	5.6
Adopters benefits#	358.7	368.5
Non-adopters#	-5.4	-4.5

UCR = Unit Cost Reduction; # = Million dollars

8. Summary and Conclusions

The whole series of short-duration wilt resistant chickpea varietal releases in India starting in the early ’90s was a product of strategic research for development partnerships by ICRISAT and the Indian NARS. Initially targeting the research domains in the southern regions of India, breeding has been directed towards the development of early maturing varieties suitable for environments where the growing season is short and where drought escape is an essential characteristic of cultivars for raising a successful crop. The broader international mandate of the crop improvement scientists at ICRISAT, however, expanded the ultimate target for the applicability of short-duration varieties for the global research domains delineated by specifically defined parameters – latitude, length of growing period, temperature and soil type. The low latitude (<20°) regions of the world with dry hot climate and vertisol soils were grouped in this homogenous Research Domain 1, covering not only the Deccan and southern Indian states of Andhra Pradesh, Karnataka and southern Maharashtra; but also similar agro-ecological zones in Myanmar, Bangladesh, Central Ethiopia, Tanzania and other countries around the world.

The successful release of improved early maturing chickpea cultivars benefited from the systematic evaluation of breeding lines and accessions from the ICRISAT germplasm collection and harnessed the effective field, greenhouse and laboratory procedures developed at ICRISAT for screening against fusarium wilt. Through the ’80s, early-maturing resistant lines were screened, identified and made available to NARS partners for their breeding programs. The continuous development of the original chickpea collection sown in a wilt-sick plot at ICRISAT in Patancheru which were re-sown for further purification found their way to on-station trials through the AICRP program in India. Multi-location screening for resistance and short duration, and on-farm adaptation trials were simultaneously undertaken through cooperative trials involving ICRISAT and several NARS research institutions globally. These joint efforts produced the first batch of releases in the early ’90s (eg, ICCV 2, ICCV 37, Akaki, Barichhola, Schwe Kyehman among others). A second batch of releases followed in the late ’90s to early 2000s (JG 11, KAK 2, Sacho, Chefe, Yezin series and Sona). While the critical binding constraint of seed multiplication limited the uptake of the first set of releases particularly in India, a contributing factor in the low uptake of the first batch of releases was seemingly also the lack of farmer readiness to adopt short-duration cultivars at that time. However, farmers were ready for the cultivars at the time of the release of the second series particularly JG 11 and KAK 2. The second batch was adequately supported by a strong partnership of research, dissemination and extension with a massive seed multiplication program involving ICRISAT, the national programs and the extension and seed multiplication sector. Between 2000 and 2003, scientists from ANGRAU, JNKVV-Jabalpur and ICRISAT pushed aggressively for meeting the high demand for improved chickpea short-duration cultivars soon after their release in 1999. Continuing seed multiplication and extension were sustained through the Andhra Pradesh State Seeds and Development Corporation (APSSDC). Further seed multiplication through the Tropical Legumes II Project PVS trials (TL II 2008-2013 supported by BMGF) in southern India further boosted the uptake in AP and Karnataka states.

The entire process, from selection to the release of the first set of short-duration (or early maturing) varieties in 1993, involved an average total of 4 years of strategic research and 12 years of applied and adaptive research conducted jointly by ICRISAT and NARS. The second set of releases which became very popular and quickly replaced the earlier dominating variety Annigeri was finally produced in 1999, accounting for six additional years of research and development. The Andhra Pradesh and Madhya Pradesh national programs together with ICRISAT invested another three years of continuous massive seed multiplication together with APSSDC. Subsequently additional support came from the TL II Project commencing in 2008.

A systematic tracking approach was developed using a representative sample survey conducted in the state of Andhra Pradesh. This was complemented by an analysis of available secondary district and sub-district level data on area, production and yield, and seed sector information that assured a robust sampling frame. The adoption and impact surveys as well as an in-depth understanding from the temporal changes in area, production and yield revealed the fast changing cropping patterns as a result of key drivers of technology adoption and other sources of growth. The analysis harnessed both the time series data from 1966-2012 and spatial analysis using GIS tools of geo-referenced parameters which related to the chickpea homogeneous research domains. Farm level reconnaissance was extensively used in gaining an understanding of the underlying qualitative factors not covered in the formal representative survey.

The results of the study clearly demonstrate the significant impact primarily of JG 11, KAK 2 and other improved cultivars released in the state of Andhra Pradesh during the period of 1999 to early 2000s. JG 11 (a desi short-duration variety) and KAK 2 (a kabuli short-duration variety) principally have been taken up in farmers' fields across the chickpea growing areas primarily in the rainfed regions of the state. Diffusion to the districts beyond initially targeted regions and countries outside India also occurred. This report covers the measured impacts in the state of Andhra Pradesh and a subsequent sequel series of studies will also consider the impact in other countries. The above cultivars occupy almost 90% of the area in the chickpea growing districts of Andhra Pradesh. While non-availability of the seeds constrained the adoption of the first batch of short-duration varietal releases in the early '90s, the subsequent R4D effort by ICRISAT and NARS, which included a massive investment in making the improved short-duration and fusarium wilt-resistant seeds available to farmers through partnerships of the research, extension, seed multiplication and philanthropic agencies in fact created a wave of grey-to-green revolution in seven districts comprising the rainfed regions of the state.

The new short-duration cultivars' yields were about 37% higher than the best cultivar previously available. It reduced unit cost by about 22% or by an average of $144 per ton. The net present value of welfare benefits from short-duration fusarium wilt-resistant research was estimated to be approximately $359 million (baseline scenario) based on the most reasonable conditions describing the present socio-economic situation of the state and the global economy. However, the total welfare benefits have increased marginally to US $ 388.4 million when we used the dis-aggregated UCRs across production environments (PEs). This represents an internal rate of return (IRR) of 28 percent on the funds invested.

During the field reconnaissance visits and other interactions, farmers confirmed that they are better-off after adoption of short-duration chickpea cultivars in Andhra Pradesh, especially cultivars JG 11 and KAK 2. Other impact dimensions including qualitative indicators are planned as a follow-up to this quantitative assessment to cover sustainable intensification, nutrition and gender. Focus group meetings informed that as adopters' average household incomes have gone up, the food intake and consumption have improved when compared with a decade ago and that they are investing more in children's education and health. Additional metrics development will be investigated: eg, agricultural intensification by leasing in land, change in tenancy and land allocation, or legumes having a range of important nutritional properties or possible qualitative indicators showing that increases in legume productivity favor women.

The comprehensive analysis of adoption and impact in this study used the survey data to address farm level responses with respect to diffusion, adoption, dis-adoption, input use, crop management and unit cost reduction in chickpea production. It aimed to answer many inter-linked issues in technology adoption, emerging collective or group action to capture economies of scale, agricultural intensification and commercialization. The quantitative analysis showcases the impact of chickpea improved technology in Andhra Pradesh with understanding of the underlying socio-economic, institutional and policy drivers for technology adoption and enhanced household welfare.

The main message from the comprehensive analysis is that significant research benefits have been achieved from the wide adoption of short-duration improved chickpea varieties in the rainfed regions of Andhra Pradesh in India. This technology is applicable beyond Andhra Pradesh's borders and is likely to be diffused further and raise the production potentials, thereby significantly increasing the welfare benefits from the research investments made by ICRISAT and NARS partners. These research findings show that significant gains can be achieved by enabling a 'Legume Revolution', harnessing the rainfed regions in South Asia and sub-Saharan Africa.

Ultimately, better focused research directly addressing the farmers' needs for short-duration chickpeas in southern India generated a technology revolution in the rainfed areas of Andhra Pradesh. The benefits from the first wave of research products released in the early '90s were derailed by lack of adoption. The continuing strategic partnerships between ICRISAT and NARS in technology development generated a second wave of research products of short-duration, wilt-resistant cultivars that expanded production levels as a result of yield gains that translated to lower unit costs for farmers. It converted even non-traditional chickpea growers to realize substantial increase in incomes in chickpea production. The significant diffusion coupled with policy conducive to widespread adoption and institutional support from relevant public or private sector seed multiplication and extension systems generated a revolution in chickpea production in rainfed areas which may go unsurpassed for many years.

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Appendices

Appendix 1. Broad Shifts in cropping patterns

The country's gross cropped area has increased significantly from 162.5 m ha in triennium 1968-1970 to 193.78 m ha by the triennium period 2008-2010 to meet the rising demand for food from the rapidly growing population. Among different crops, the major share is occupied by rice (22.42%) followed by wheat (14.67%), fruits and vegetables (7.44%), cotton (5.29%), soybean (4.96%), pearl millet (4.69%), maize (4.3%) and chickpea (4.34%) during the triennium period of 2008-10. For a deeper understanding of the crop-wise shifts, an analysis of the last four decades cropped area data is summarized in Appendix 1.1.

The performance of rice was pretty stable from the early 1960s until 2010. Area under wheat has increased significantly from 10.43% in 1968-1970 to 14.67% by 2010 in the country's gross cropped area. This major shift in favor of wheat area might be because of the impact of green revolution and quicker adoption of improved cultivars. Under the cereals category, the area under maize also showed impressive growth because of increased demand for food, feed and industrial segments. Crops such as sorghum have lost its significance drastically during the four-decade period and the corresponding reduction in area has been taken away by soybean and cotton. Pearl millet also lost some proportion of area but it is still concentrated in specific niches. Major factors attributed for these shifts are increased household income, changing food habits and subsidized PDS system (especially on rice and wheat).

The cropped area under pulses has resumed conspicuously because of significant progress in development and adoption of short-duration, disease resistant cultivars. Chickpea is major crop which occupied significant area followed by pigeonpea, lentils, moong and urad bean. During late 1970s and 1980s chickpea cropped area significantly declined due to high incidence of pests and diseases and improved access to irrigation facilities and shifted to wheat. However, the area picked up significantly by the late 1990s after the introduction of short-duration cultivars in southern and central India. Overall, the absolute cropped area of chickpea increased marginally. Pigeonpea has increased its share slightly from 1.59 to 1.93% during the four-decade period.

Among oilseeds, soybean and rape and mustard seeds have diffused much faster than other crops. Groundnut significantly declined its share from 4.42 to 3.01 in the same period. Commercial crops such as cotton, fruits and vegetables have penetrated well into different cropping systems in India.

Appendix 1.1. Broad shifts in cropping patterns at the all-India level (% shares in area).					
Crop	1968-1970	1978-1980	1988-1990	1998-2000	2008-2010
Rice	23.02	23.22	23.00	23.82	22.42
Wheat	10.43	12.98	13.04	14.28	14.67
Sorghum	11.22	9.41	7.95	5.29	3.90
Maize	3.57	3.38	3.22	3.40	4.30
Pearl millet	7.68	6.50	6.07	4.96	4.69
Pigeon pea	1.59	1.59	1.94	1.86	1.93
Chickpea	4.66	4.12	3.78	3.50	4.34
Lentil	NA	0.54	0.61	0.77	0.74
Groundnut	4.42	4.14	4.64	3.68	3.01
Rape and mustard seed	1.92	2.15	2.83	3.01	3.23
Sesamum	1.47	1.40	1.33	0.86	1.00
Linseed	1.10	1.04	0.62	0.77	0.77
Castor	0.25	0.26	0.39	0.45	0.43
Niger	0.29	0.34	0.33	0.31	0.20
Safflower	0.36	0.42	0.45	0.23	0.14
Sunflower	0.07	0.07	0.71	0.74	0.73
Soybean	0.02	0.27	1.19	3.38	4.96
Cotton	4.70	4.66	4.08	4.70	5.29
Sugar cane	1.62	1.62	1.90	2.23	2.32
Jute and mesta	0.61	0.73	0.52	0.55	0.46
Tobacco	0.27	0.25	0.22	0.21	0.21
Guar seed	0.73	1.32	1.32	NA	NA
Fruits and vegetables	2.23	2.77	3.56	4.35	7.44
Condiments and spices	1.04	1.22	1.32	1.52	1.30
Others	16.52	15.36	14.75	14.93	12.37
Total cropped area	100.00	100.00	100.00	100.00	100.00

Appendix 1.2. Shifts in chickpea cropped area across major states (% share).

	Madhya Pradesh			Andhra Pradesh			Maharashtra			Karnataka			Uttar Pradesh			Rajasthan		
Crops	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10
Rice	21.20	9.10	7.50	28.44	26.23	31.78	7.42	6.97	6.67	8.78	10.52	11.99	21.25	22.93	22.40	0.73	0.59	0.62
Wheat	14.86	19.64	19.65	0.07	0.10	0.09	3.27	3.36	5.04	1.79	2.13	2.13	34.74	36.58	38.24	10.50	11.12	10.74
Jowar	5.64	3.66	2.15	8.24	5.21	2.32	27.93	21.93	18.21	17.44	15.22	10.55	1.83	1.20	0.78	3.73	3.39	3.03
Maize	3.77	4.61	3.97	1.31	0.86	6.01	0.82	1.63	2.89	2.37	5.33	9.50	4.22	3.50	3.00	4.96	5.59	4.93
Pearl millet	0.64	0.94	0.80	2.42	4.57	0.43	8.91	6.51	4.34	2.93	2.40	2.32	3.06	3.40	3.44	24.23	25.51	23.71
Pigeonpea	1.88	1.62	1.86	2.49	3.74	3.90	4.87	4.79	5.04	3.61	4.41	5.53	2.07	1.49	1.28	0.11	0.11	0.09
Chickpea	9.60	12.89	14.32	0.55	2.99	4.64	2.71	3.66	5.73	1.91	4.18	7.02	4.16	3.29	2.31	6.43	4.56	5.88
Other pulses	8.21	8.14	7.06	9.38	10.18	6.19	7.98	7.42	4.76	7.77	8.23	6.89	5.12	5.94	5.98	6.54	4.66	11.90
Groundnut	1.16	1.13	0.93	18.65	12.69	11.85	3.26	1.87	1.47	10.39	7.26	6.65	0.53	0.38	0.36	16.69	16.20	1.49
Rape and mustard seed	2.68	2.48	3.56	0.04	0.02	0.04	0.04	0.05	0.03	0.04	0.05	0.04	4.88	3.29	2.79	13.41	9.88	13.22
Sesamum	0.95	0.71	1.11	1.34	1.11	0.75	1.32	0.54	0.25	1.06	0.59	0.58	0.60	0.59	1.24	2.78	1.47	2.50
Linseed	1.70	0.79	0.58	0.05	0.04	0.01	0.65	0.28	0.17	0.21	0.14	0.10	0.68	0.34	0.24	0.19	0.01	0.01
Castor	0.01	0.01	0.00	2.17	2.20	1.25	0.03	0.10	0.04	0.19	0.16	0.15	0.00	0.00	0.00	0.07	0.24	0.60
Safflower	0.02	0.00	0.00	0.16	0.15	0.10	2.29	1.21	0.81	1.29	0.80	0.52	0.00	0.00	0.00	0.00	0.00	0.00
Sunflower	0.10	0.01	0.00	2.53	3.20	2.51	2.25	1.28	1.02	10.08	7.49	5.82	0.13	0.02	0.03	0.03	0.00	0.00
Soybean	12.32	22.58	25.41	0.02	0.35	1.08	1.81	6.02	13.03	0.31	0.58	1.28	0.11	0.12	0.04	1.37	2.91	3.55
Cotton	2.12	2.93	2.99	5.80	7.49	11.99	12.21	13.22	15.66	4.78	3.80	3.73	0.05	0.02	0.02	2.56	2.23	1.62
Sugarcane	0.21	0.22	0.31	1.42	1.80	1.38	1.91	2.43	3.68	2.26	2.98	2.75	7.25	8.27	8.21	0.13	0.04	0.03
Other crops	12.95	8.54	7.78	14.92	17.05	13.69	10.30	16.73	11.16	22.78	23.71	22.46	9.32	8.64	9.65	5.54	11.49	16.08
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Percent shares in those respective states during that period.

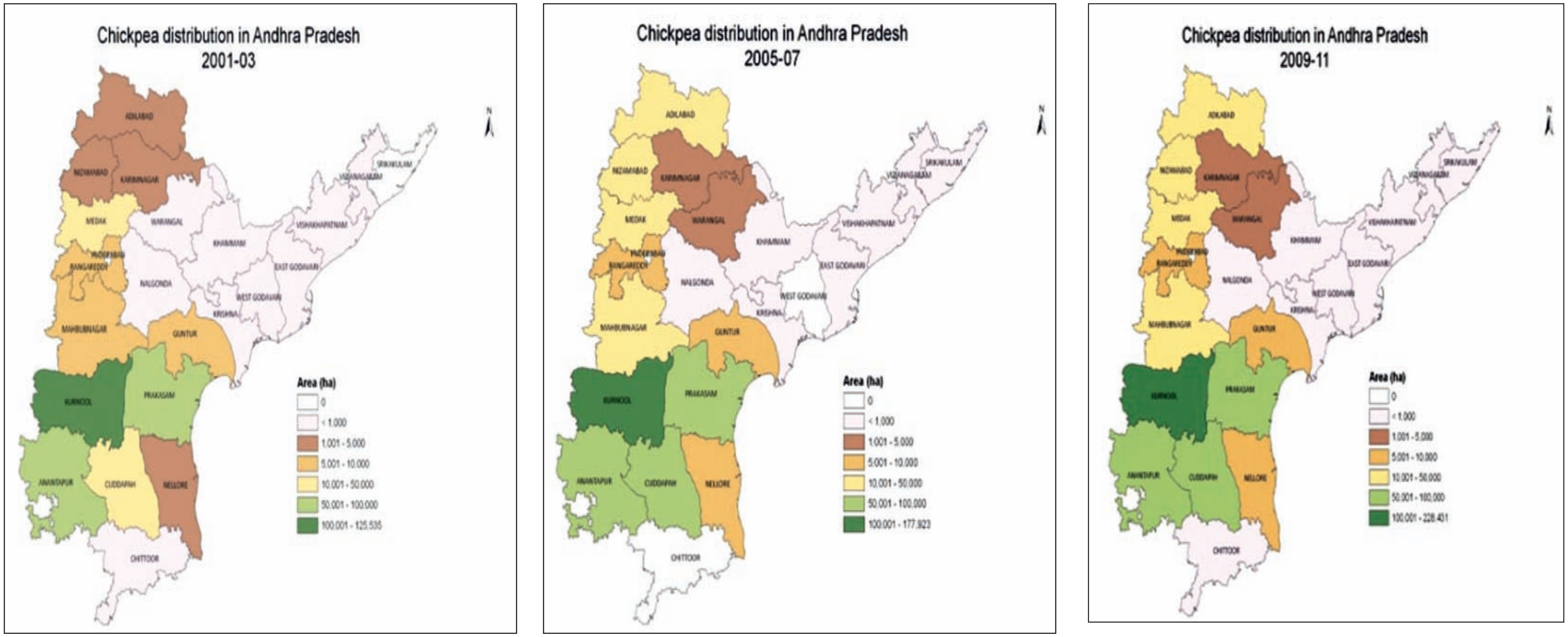

Figure 1.1. District-wise patterns of chickpea expansion in Andhra Pradesh, 2001-11 (area in '000 ha).

Appendix 1.3. Shifts in cropping patterns among major chickpea growing districts of Andhra Pradesh, 1991-93 to 2001-03 (% area).

	Prakasam		Kadapa		Anantapur		Kurnool		Nizamabad		Mahabubnagar		Medak		Andhra Pradesh	
Crop	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03
Rice	21.15	15.07	14.06	11.30	5.14	4.45	7.46	6.47	36.73	37.58	12.76	12.22	21.76	16.77	28.44	26.23
Wheat	0.00	0.00	0.02	0.01	0.03	0.02	0.06	0.10	0.45	0.53	0.02	0.02	0.54	0.64	0.07	0.10
Jowar	4.97	1.57	3.91	2.16	4.35	2.20	14.66	11.26	9.60	9.35	27.84	25.01	24.50	14.65	8.24	5.21
Bajra	4.19	2.64	1.01	0.95	0.50	0.19	1.79	1.40	1.11	1.40	1.78	1.91	0.52	0.16	1.31	0.86
Maize	1.58	1.65	0.02	0.01	0.10	0.53	0.07	0.32	18.28	16.57	0.32	2.00	15.14	18.07	2.42	4.57
Ragi	1.56	0.69	0.42	0.18	1.15	0.47	0.00	0.00	0.03	0.01	2.58	1.92	0.18	0.00	1.09	0.63
Other minor millets	2.62	0.37	0.22	0.05	0.76	0.10	4.11	1.82	0.00	0.00	0.63	0.43	0.09	0.03	1.16	0.42
Cereals sub- total	36.06	22.00	19.67	14.66	12.04	7.97	28.16	21.39	66.21	65.46	45.93	43.51	62.73	50.32	42.74	38.02
Pigeonpea	5.01	11.43	1.84	4.48	2.48	3.26	2.11	3.34	0.91	0.84	4.80	5.22	2.68	3.89	2.49	3.74
Chickpea	0.76	11.02	1.15	10.96	0.84	4.90	2.45	14.02	1.06	1.05	0.22	0.45	2.81	5.47	0.55	2.99
Other pulse crops	5.07	11.03	0.14	1.26	1.24	0.58	0.44	1.88	7.20	7.83	4.73	5.84	10.54	19.19	9.38	10.18
Pulses sub-total	10.84	33.47	3.13	16.70	4.56	8.73	5.00	19.25	9.17	9.73	9.75	11.51	16.04	28.55	12.42	16.92
Groundnut	10.63	1.20	57.94	29.08	72.71	70.67	33.51	21.02	2.40	2.36	20.56	17.18	1.76	0.82	18.65	12.69
Sesamum	2.49	1.96	0.84	0.88	0.02	0.00	0.08	0.02	0.38	0.36	0.15	0.14	0.54	0.41	1.34	1.11
Castor	4.13	2.40	0.25	0.61	0.23	0.23	0.08	0.84	0.04	0.03	11.72	14.12	0.42	0.63	2.17	2.20
Sunflower	0.89	2.41	5.67	18.73	2.84	5.94	15.31	19.45	2.36	2.12	4.60	4.22	2.68	0.91	2.53	3.20
Soybean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.35
Other oilseed crops	0.63	0.28	0.07	0.03	0.48	0.31	0.43	0.31	0.66	0.71	0.49	0.51	1.59	1.45	0.45	0.35
Oilseeds sub total	18.78	8.27	64.77	49.34	76.28	77.15	49.40	41.66	5.85	5.59	37.52	36.17	6.98	4.22	25.17	19.91
Sugarcane	0.06	0.05	0.21	0.17	0.15	0.04	0.04	0.02	4.98	6.62	0.01	0.01	4.02	6.71	1.42	1.80
Cotton	8.39	5.68	1.40	3.82	1.28	0.66	8.16	6.34	4.38	4.10	3.88	5.53	2.15	1.80	5.80	7.49
Other crops	25.87	30.54	10.83	15.31	5.70	5.45	9.24	11.32	9.41	8.51	2.91	3.28	8.07	8.40	12.46	15.86
Other crops sub-total	34.32	36.26	12.43	19.30	7.13	6.15	17.44	17.69	18.77	19.23	6.79	8.81	14.24	16.91	19.68	25.15
Total cropped area	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Percent shares in those respective states during that period.

Appendix 1.4. Shifts in cropping pattern among major chickpea growing districts of Andhra Pradesh, 2001-03 to 2008-10 (% area).

	Prakasam		Kadapa		Anantapur		Kurnool		Nizamabad		Mahabubnagar		Medak		Andhra Pradesh	
Crops	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10
Rice	15.07	20.47	11.30	13.27	4.45	4.95	6.47	12.67	37.58	37.72	12.221	13.182	16.77	20.58	26.23	30.75
Wheat	0.00	0.00	0.01	0.01	0.02	0.01	0.11	0.06	0.53	0.60	0.021	0.009	0.64	0.51	0.10	0.08
Jowar	1.57	0.82	2.16	1.59	2.20	2.76	11.26	6.54	9.35	8.61	25.007	21.361	14.65	6.59	5.21	2.24
Bajra	2.64	1.83	0.95	0.73	0.19	0.14	1.40	0.76	1.40	1.46	1.912	1.800	0.16	0.08	0.86	0.42
Maize	1.65	1.08	0.01	0.32	0.53	1.20	0.32	1.91	16.57	15.56	1.998	4.779	18.07	17.45	4.57	5.81
Ragi	0.69	0.21	0.18	0.03	0.47	0.24	0.00	0.00	0.01	0.00	1.919	1.435	0.00	0.00	0.63	0.34
Other minor millets	0.37	0.11	0.05	0.03	0.10	0.05	1.82	0.78	0.00	0.00	0.427	0.391	0.03	0.00	0.42	0.21
Cereals sub-total	22.00	24.51	14.66	15.99	7.97	9.35	21.39	22.73	65.46	63.95	43.505	42.957	50.32	45.21	38.02	39.86
Pigeonpea	11.43	10.11	4.48	2.83	3.26	3.73	3.35	4.54	0.84	0.77	5.217	5.916	3.89	4.70	3.74	3.78
Chickpea	11.02	12.82	10.96	14.43	4.90	8.05	14.02	23.00	1.05	1.18	0.447	0.863	5.47	6.77	2.99	4.49
Other pulse crops	11.03	4.06	1.26	1.06	0.58	0.57	1.88	1.54	7.83	9.06	5.845	6.938	19.19	13.33	10.18	6.00
Pulses sub-total	33.47	26.99	16.70	18.32	8.73	12.35	19.25	29.08	9.73	11.00	11.509	13.718	28.55	24.79	16.92	14.27
Groundnut	1.20	1.24	29.08	28.54	70.67	69.13	21.02	20.82	2.36	1.94	17.175	14.060	0.82	0.31	12.69	11.47
Sesamum	1.96	2.75	0.88	1.28	0.00	0.00	0.02	0.06	0.36	0.35	0.145	0.124	0.41	0.15	1.11	0.72
Castor	2.40	1.12	0.61	0.22	0.23	0.20	0.85	4.14	0.03	0.02	14.122	15.808	0.63	0.16	2.20	1.21
Sunflower	2.41	4.03	18.73	14.62	5.94	3.56	19.45	12.27	2.12	2.01	4.221	3.761	0.91	2.27	3.20	2.43
Soybean	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.00	0.000	0.000	0.00	0.55	0.35	1.04
Other oilseed crops	0.28	0.03	0.03	0.14	0.31	0.08	0.32	0.49	0.71	0.71	0.509	0.197	1.45	1.25	0.35	1.28
Oilseeds sub total	8.27	9.18	49.34	44.82	77.15	73.03	41.66	37.79	5.59	5.01	36.172	33.949	4.22	4.70	19.91	18.15
Sugarcane	0.05	0.04	0.17	0.08	0.04	0.02	0.02	0.15	6.62	7.19	0.008	0.005	6.71	5.04	1.80	1.33
Cotton	5.68	5.97	3.82	2.59	0.66	0.25	6.35	3.83	4.10	3.49	5.526	5.582	1.80	11.33	7.49	11.35
Other crops	30.54	33.31	15.31	18.21	5.45	5.00	11.32	6.43	8.51	9.35	3.279	3.790	8.40	8.92	15.86	15.04
Other crops sub-total	36.26	39.31	19.30	20.87	6.15	5.26	17.69	10.40	19.23	20.03	8.813	9.377	16.91	25.29	25.15	27.73
Total cropped area	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Percent shares in those respective states during that period.

Crop shifts across major chickpea growing states

The summary details about major shifts in cropping pattern of main chickpea growing states are tabulated in Appendix 1.2. States such as Madhya Pradesh, Karnataka, Maharashtra, Uttar Pradesh and Rajasthan represent more than 90% cropped area of chickpea in India. In Madhya Pradesh, chickpea was adopted well and increased its share from 9.6 in early 1990s to 14.32% (1½ times) by the end of 2008-10. Rice, sorghum and linseed lost their shares respectively and this area has been diverted to crops such as soybean and chickpea. In the case of Andhra Pradesh, the performance of chickpea increased significantly from 0.55 in early 1990s to 4.64% (8.5 times) by the end of triennium 2008-10. It was a salient revolution in chickpea area in the state during short span of time. Sorghum, pearl millet, groundnut, castor and other pulses (moong and urad beans) have been replaced with chickpea, rice, cotton and maize. The chickpea area share in Maharashtra has doubled during the last two decades (1990-2010). Cropped area under sorghum, pearl millet, safflower, sunflower, groundnut and other pulses have given away to cotton, soybean and chickpea. The chickpea area share in the total cropped area in Karnataka has increased significantly from 1.91 to 7.02% (3.5 times). Due to high risk and un-remunerative incomes in sorghum, groundnut and sunflower cultivation, the dryland farmers switched over to chickpea, maize and pigeonpea. Typically, Uttar Pradesh has lost remarkable area under chickpea cultivation since early 1990s. Due to improved access to irrigation facilities and availability of green revolution technologies, farmers have intensified their cereal-based cropping systems (rice and wheat) further. However, the area under other pulses (moong, urad, lentils and cowpeas) was stable during the same period. Relatively, the chickpea area under Rajasthan was dwindling, gone down in early 2000 and increased by end of 2008-2010. This shifting may be due to climatic conditions/variations in Rajasthan. Except groundnut, all other crops were exhibited stable patterns in Rajasthan between 1990 and 2010.

Crop shifts across major chickpea growing districts in Andhra Pradesh

The major shifts in cropping pattern across chickpea growing districts in Andhra Pradesh are summarized in Appendix 1.3. (P1: 1991-93 to 2001-03) and 1.4 (P2: 2001-03 to 2008-10). To critically examine the shifts in cropping pattern, the study period has been divided into two ie, period1: 1991-93 to 2001-03 and period2: 2001-03 to 2008-10.

During the first period, the area under chickpea in Kurnool district has expanded from 2.45 to 14.02% (5.7 times) in total cropped area (see Appendix 1.3). Sorghum, other minor millets, groundnut and cotton have lost their cropped areas and given way to chickpea cultivation. Chickpea area in Prakasam district has increased quite remarkably from 0.76 to 11.02% (14.5 times) of the total cropped area. Chickpea has replaced sorghum, millets, cotton, groundnut and sesamum crops due to its high productivity, good remunerative prices and less risk in its cultivation. In the case of Kadapa, area under chickpea has increased nearly 9.5 times (from 1.15 to 10.96%) during first period. Rice, sorghum and groundnut have been replaced by chickpea and sunflower significantly. Kurnool, Prakasam and Kadapa were ahead of all other districts in the adoption of the newly developed short duration chickpea cultivars.

Anantapur is another major district which increased the chickpea cultivation significantly (from 0.84 to 4.90%) by sacrificing areas from sorghum and ragi crops. Nizamabad and Mahabubnagar districts did not respond well for short-duration chickpea cultivars between 1990 and 2000. The area coverage under chickpea in these districts was minimal. However, Medak district was a traditional chickpea grower and increased its area twice over during the same period. Sorghum and rice sacrificed area for expansion of chickpea in this district.

During the second period, the expansion pattern of chickpea area across seven districts is presented in Figure 1.1. Kurnool expanded its chickpea area to almost double by sacrificing the cropped areas from sorghum and sunflower crops (see Appendix 1.4). But, the expansion was rather low in Prakasam district. However, chickpea replaced other pulse crops (moong and urad) significantly in the district due to its higher net incomes. The chickpea area growth in Kadapa was marginal (from 10.96 to 14.43%) and it substituted sunflower crop significantly in the district. Expansion of chickpea in Anantapur district was slightly lower (from 4.90 to 8.05 %) during the last decade. Sunflower cropped area lost marginally and gave way to chickpea cultivation in the district. Nizamabad, Mahabubnagar and Medak districts have expanded their areas under chickpea by substituting mainly sorghum, groundnut and other pulses and sunflower.

Appendix 2: Extent of diffusion bounded by access to irrigation and beyond Andhra Pradesh

The penetration of the crop in two districts of Nizamabad and Adilabad was observed in the early 2000s but reached its peak in 2008. It is noted that expansion may have been limited by increased irrigation investments in these regions. Further diffusion of improved cultivars may also be anticipated even in the irrigated Krishna and Godavari rice-dominated districts, where chickpea has a potential to grow immediately after rice cultivation (rice–chickpea cropping system). Nevertheless, the competitive advantage of chickpea over other crops or cropping systems significantly depends on the profitability of the chickpea *vis-a-vis* existing crops grown in the system.

Determination of the possible extent of area expansion is determined by re-examining some more details of the chickpea research domains. As discussed above, the research domain for chickpea production has been delineated by five variables: rainfall, temperature, soil type, latitude and length of growing period. One variable that has not been considered, and may be an important factor, is the extent of irrigation as this variable likely influences the suitability and competitiveness of chickpea production in the region. Thus, available spatial maps and district level data were further analyzed to explore the possible areas of expansion. In fact, further analysis of sub-district data (see Appendices 2.1 and 2.2) may identify possible niches of non-irrigated vertisols where chickpea production may expand (Figure 2.3 and Figure 2.4).

Traditional access to water in Andhra Pradesh is illustrated through three river systems – Godavari, Krishna and Penna – that flow through the state as shown in Figure 2.1. Investments in irrigation started in the ’60s and continued to expand especially around these river systems as shown in the spatial distribution of the extent of irrigation (Figure 2.2). Complementary time series data on percent net cropped area indicates aggregated district level irrigation identifying that the specific districts where short-duration chickpea has expanded are in the remaining rainfed regions of Andhra Pradesh which exactly corresponds to the seven districts included in the sampling frame of this study. The expansion of chickpea production is shown to be possible but limited in the vertisol regions of Adilabad in the northwest Andhra Pradesh. Further expansion to Nizamabad (NW region of AP) is seemingly very limited due to the massive investments in the districts. Furthermore, the increasing urbanization of the districts of Medak, Rangareddy and Mahabubnagar (due to its nearness to the urban center of Hyderabad) presents alternative diverse options to agriculture and chickpea production. Nevertheless, this one large district of Adilabad, which is primarily vertisols remains to be primarily rainfed (only about 12-13 % net irrigated area which is almost similar to the percentage irrigation in chickpea growing district of Anantapur) presents viable opportunities for further expansion of chickpea production in Andhra Pradesh.

Figure 2.1. Three river systems flowing through the state of Andhra Pradesh.

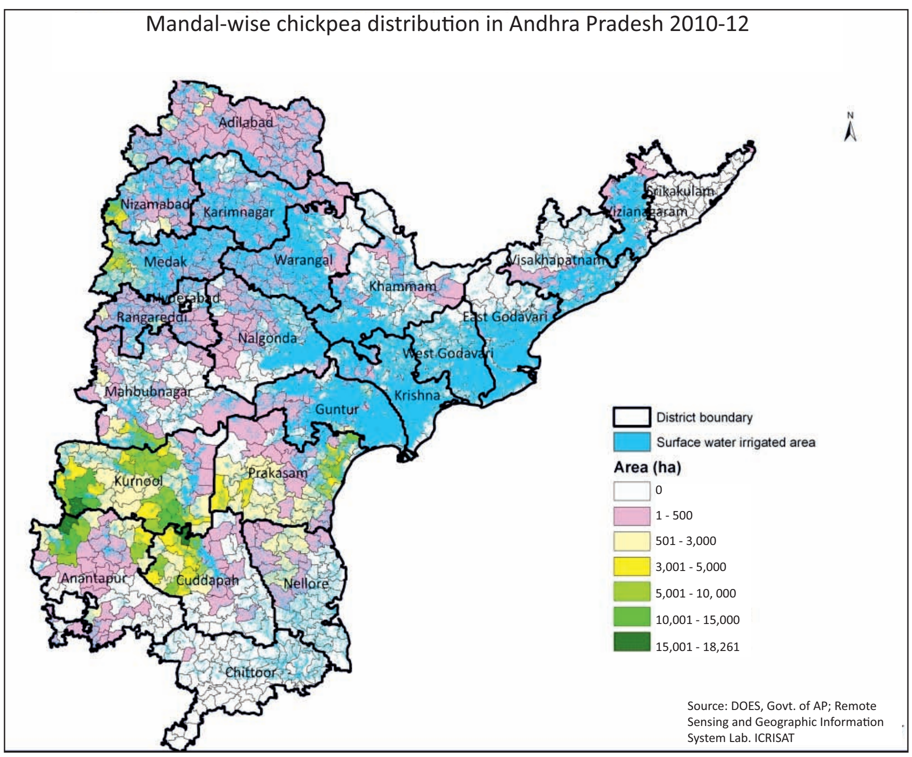

Figure 2.2. Spatial distribution of surface water irrigation area in AP, 2010-12.

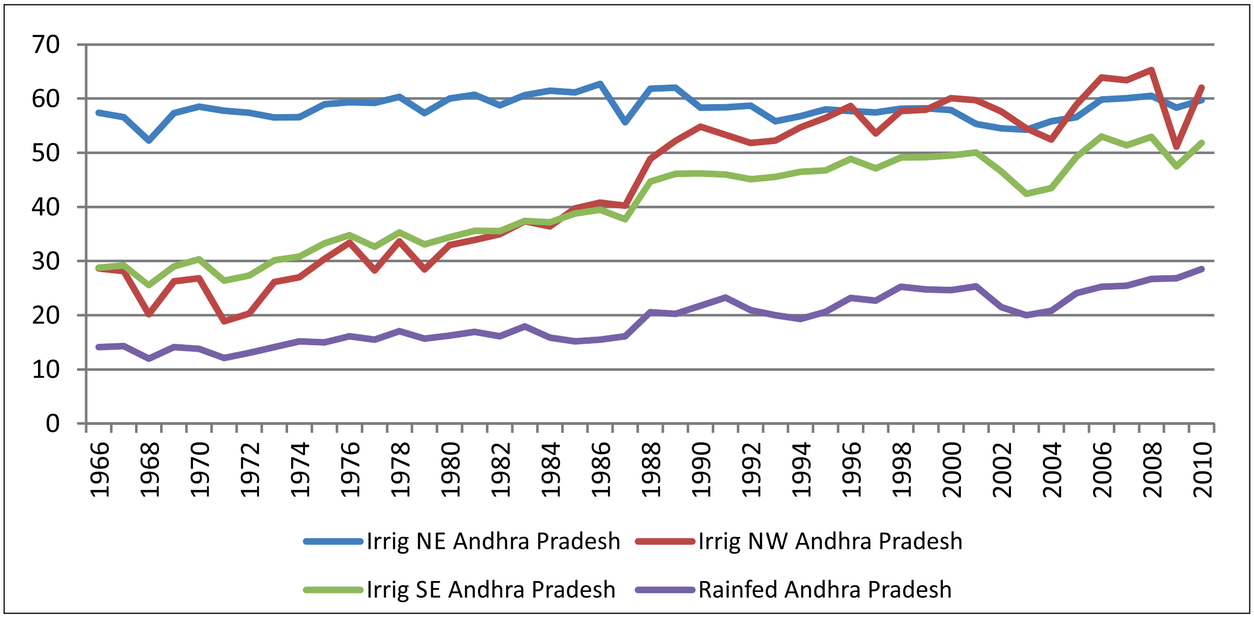

Figure 2.3. Percent net irrigated area in four regions of AP, 1966-2010.

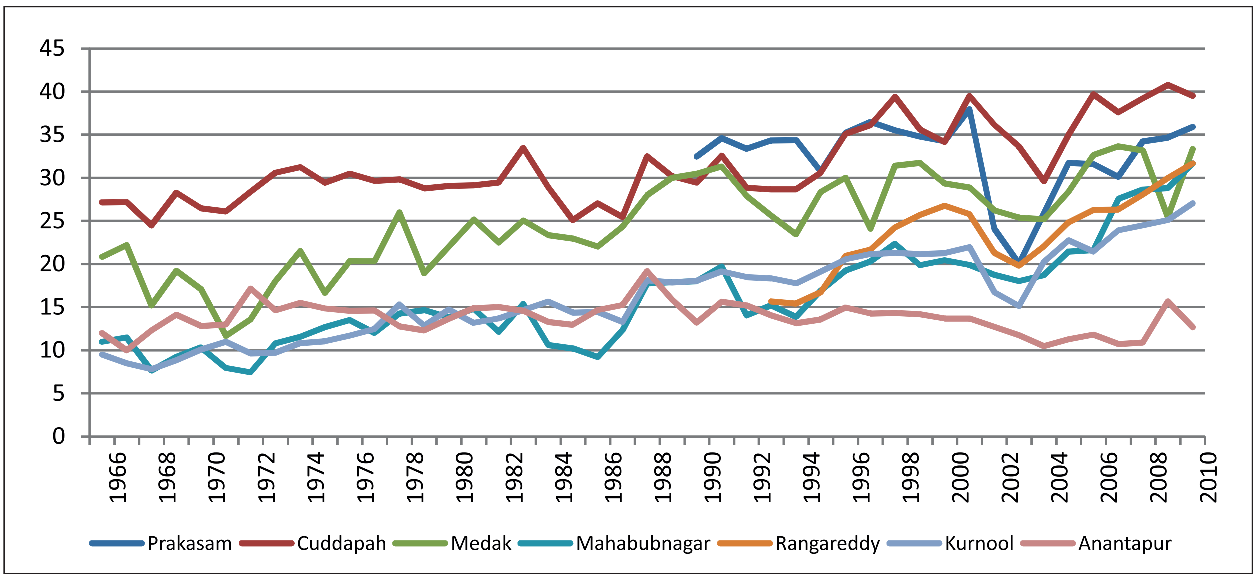

Figure 2.4. Percent net irrigated area in seven chickpea growing districts of AP, 1966-2010.

Appendix 2.1. Average percentage net irrigated area in Andhra Pradesh, 1966-2010.

Region	1966-75	1976-85	1986-95	1996-05	2006-10
Irrigated NE Andhra Pradesh	56.9	59.9	58.8	56.6	59.7
Irrigated NW Andhra Pradesh	25.3	33.9	50.5	57.1	61.1
Irrigated SE Andhra Pradesh	29.1	35.5	44.4	47.5	51.3
Rainfed Andhra Pradesh	13.8	16.3	19.8	23.2	26.5

Appendix 2.2. District level percent net irrigated area in Andhra Pradesh, 1966-2010.

District	1966-75	1976-85	1986-95	1996-05	2006-10
West Godavari	74.4	78.6	81.5	80.9	84.7
Krishna	63.2	68.2	70.1	65.7	65.4
East Godavari	61.7	64.3	62.8	64.3	67.1
Srikakulam	48.6	50.7	50.4	51.8	55.6
Visakhapatnam	36.7	37.7	38.5	35.6	38.4
Vizianagaram	24.1	-	42.3	41.2	46.9
Karimnagar	24.1	33.9	58.3	65.2	74.7
Nizamabad	37.7	47.8	55.1	62.4	61.7
Warangal	22.4	29.9	51.4	60.5	64.4
Khammam	16.9	24.1	37.2	40.4	43.8
Adilabad	5.5	7.2	10.2	14.1	13.3
Nellore	42.9	50.9	60.8	58.9	56.4
Nalgonda	19.2	27.5	33.6	37.9	52.0
Guntur	37.1	44.6	48.4	47.6	53.2
Chittoor	32.0	30.6	31.6	38.3	42.1
Prakasam	-	-	33.3	31.6	33.3
Kadapa	27.9	29.4	29.4	35.4	39.3
Medak	17.6	22.7	27.1	28.1	31.6
Hyderabad	12.1	13.8	17.8	23.3	28.4
Mahabubnagar	10.0	13.1	15.5	19.9	27.6
Rangareddy	-	-	15.9	23.3	28.4
Kurnool	9.7	13.9	17.5	20.2	24.4
Anantapur	13.6	13.9	15.0	13.1	12.4

The above scenario represents the specific situation for possible simulation in Chapter 7. In this case, it may be illustrated that the remaining rainfed vertisols of the state including the districts of Adilabad (which is currently classified under “rest of AP” may still expand its chickpea production from the current production of 71,300 tons of chickpea). This scenario considers that the increase in production is due to farmers increasing adoption of new improved varieties (JG 11, Vihar and/or KAK 2) or farmers switching from non-chickpea crops. However, this situation may be limited to districts such as Adilabad, Guntur, Nellore and Karimnagar where the area of chickpea production has increased in the mid-2000s but has already gradually declined since.

Diffusion across the borders of Karnataka and Maharashtra

Going beyond the boundaries of the state of Andhra Pradesh, Figure 2.5 presents the distribution of various soil types in the states of Andhra Pradesh and adjoining Karnataka. It is evident that while entisols and ultisols dominate, the figure indicates that the extent of presence of vertisols is much higher in Karnataka state than in Andhra Pradesh.

Spatial distribution of chickpea cropped area

The spatial distribution of chickpea area among the top three southern states are depicted in Figure 2.6 based on 2008-10 data. We can clearly conclude from the figure that chickpea has now become one of the predominant postrainy season crops in these states. Apart from Andhra Pradesh, the crop is well distributed in districts of Karnataka (Gulbarga, Bijapur, Dharwad, Raichur and Bagalkot) and Maharashtra (Ahmednagar, Beed, Latur, Osmanabad, Buldana, Akola, Washim and Aurangabad etc.). The crop spread is much more conspicuous in Maharashtra than Karnataka and Andhra Pradesh. However, Andhra Pradesh and Karnataka states completely fall under short-duration group (90-110 days) while part of Maharashtra belongs to medium maturing environment.

Figure 2.7 presents the mandal-wise distribution of chickpea crop in Andhra Pradesh for the period 2010-12. Out of the total 1120 mandals from 23 districts of Andhra Pradesh, there are only 329 mandals having chickpea grown even in one ha. They are much concentrated (at least > 3000 ha) in Kurnool districts followed by Kadapa, Prakasam and Anantapur districts.

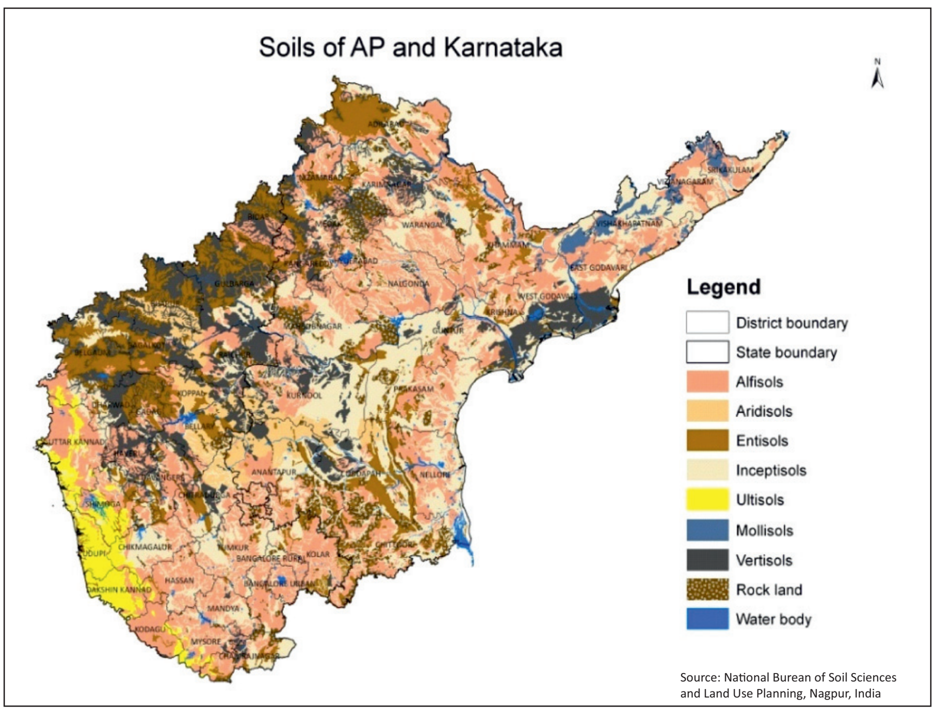

Figure 2.5. Major soil types in Andhra Pradesh and Karnataka states.

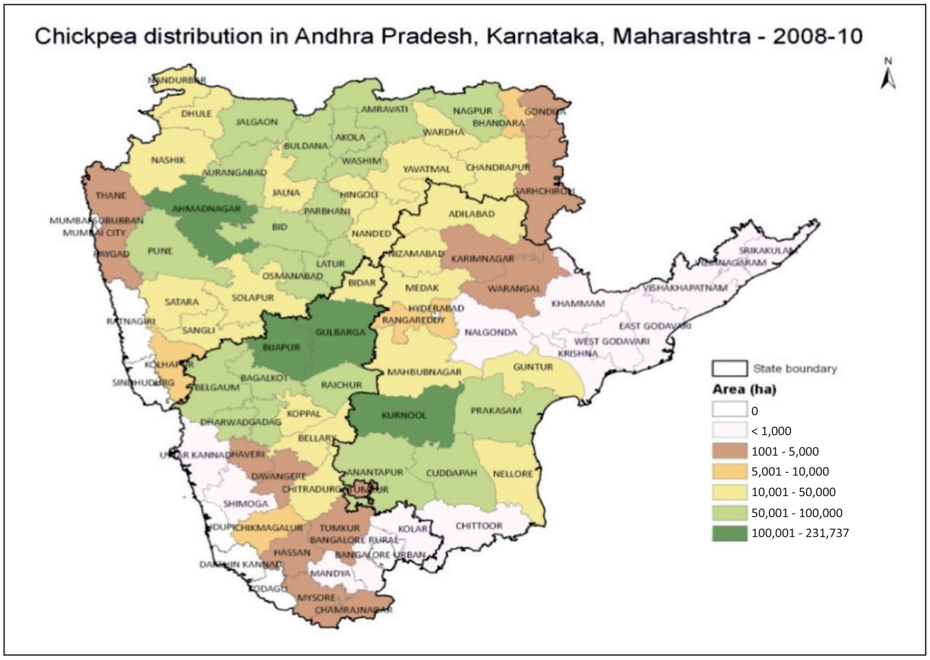

Figure 2.6. Chickpea area distribution in AP and neighboring Karnataka and Maharashtra.

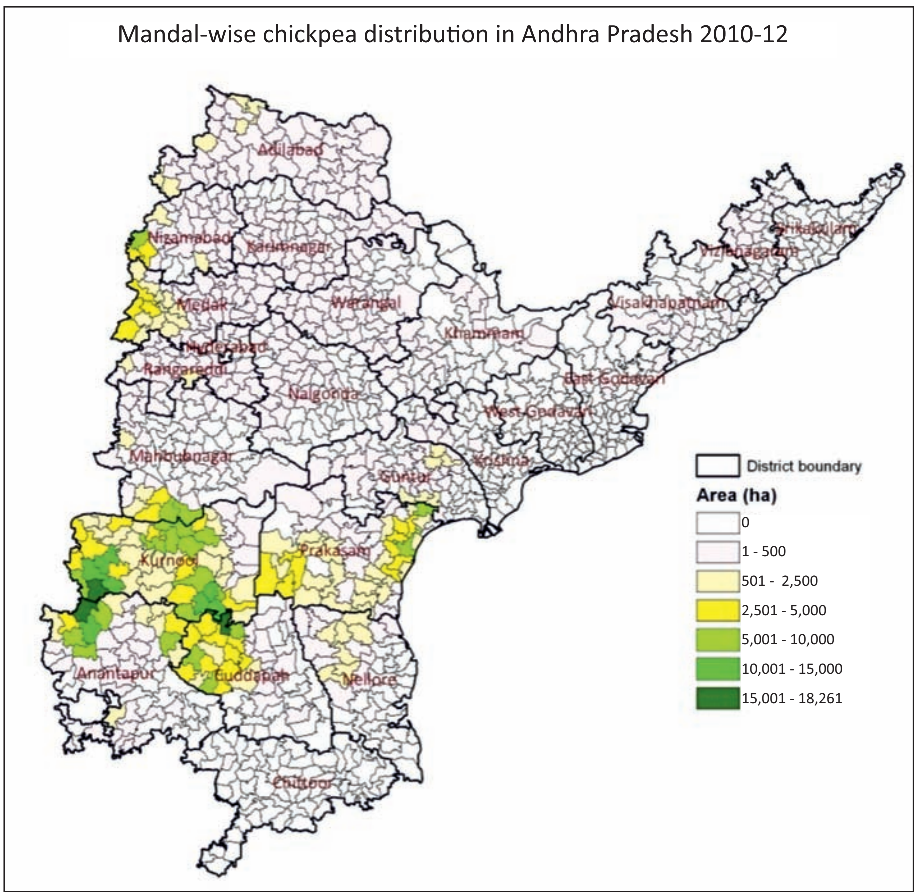

Figure 2.7. Mandal-wise area distribution of chickpea in AP, 2010-12.

Appendix 3. Characteristic features of major improved cultivars of chickpea in Andhra Pradesh.

Cultivar	Release year	Type	Duration (days)	Flower color	Seed color	Seed description	Plant type	Resistance	100-seed weight (g)	Yield (kg/ha)
Annigeri	1978	Desi	100	Pink	Yellowish brown	Round seed of medium size	Semi-spreading	Resistant to wilt disease	16-20	988-1236
Jyoti	1978	Desi	110-120	Pink	Yellowish brown	Round, smooth and small in size	Semi-spreading, plant height 40 cm	Resistant to drought	15-18	1000-1200
D 8	1982	Kabuli	145	White	Brownish yellow	Medium sized, smooth seed surface, round in shape	-	Suitable for perching purpose	15	1200-1400
ICCV 32	1984	Kabuli	135	-	-	Medium-sized, bold	-	Resistant to wilt, tolerant to root rot and pod borer	-	2600
ICCV 10 (Bharati)	1992	Desi	110	-	-	-	Semi-erect, long fruiting branches, 32-68 cm plant height	Resistant to fusarium wilt and tolerant to dry root rot and less susceptible to pod borer	-	1800-2000
Swetha (ICCV 2)	1993	Kabuli	85	White	Creamy white	Medium-sized, bold	50-60 cm	Resistant to fusarium wilt	24-26	1200-1300
JAKI 9218	2007	Desi	120	-	-	-	-	Resistant to wilt and root rot	-	1800
JG 11	1999	Desi	97	Dark pink	Light brown	Very bold and smooth	Semi-spreading	Resistant to wilt, moderately resistant to root rot and stunt, tolerant to Helicoverpa pod borer	22.5-24	1483-1730
KAK 2	1999	Kabuli	90-110	White	-	Bold	Plant medium tall and bushy, semi-spreading	Resistant to wilt	34-38	1977-2100
Kranthi (ICCV 37)	2001	Desi	90-100	Pink (reddish purple)	Light brown	Angular ram's head, smooth	Plant dwarf, semi- erect	Resistant to wilt and root rot	18.6	1600-2000
Vihar	2002	Kabuli	105-110			Large seed		Resistant to wilt	32-34	1853-1977
Digvijay	2005	-	105-110	-	Yellowish brown	Large seed	-	Wilt resistant variety	-	1800-1900
L Beg 7	2006	Kabuli	Early	-	Pearly white	Bold seed	Plant 40-60cm tall	-	32-34	-
N Beg 3	2012	Desi	-	-	-	-	-	Tolerant to drought and heat	-	-

Source: Various CVRC Reports, Government of India.

Appendix 4. Global releases of chickpea by ICRISAT & ICARDA across different countries.

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ICC 4923	Jyothi		1978	India	Jyothi
ICC 8521			1980	USA	Aztee
ICCV 1	II 208 x T3	Patancheru	1983	India	ICCC 4
ICC 13816			1984	Algeria	Yialousa
ILC 3279 (ICARDA)	ICC 19418		1984	Cyprus	Yialousa
ICC 13816			1984	Cyprus	Yialousa
F-378 x F-496	F-378 x F-496	Patancheru	1984	India	Anupam
Selection from ICCX 730089	K 850 x F 378	Patancheru	1985	Ethiopia	Mariye
Selection from ICCX 730085	L 550 x L 2	Patancheru	1985	India	GNG 149
ILC 72 (ICARDA)	ICC 12961		1985	Spain	Fardan
ILC 200 (ICARDA)	ICC 12965		1985	Spain	Zegri
ILC 200 (ICARDA)	ICC 12965		1985	Spain	Atalaya
ILC 2548 (ICARDA)			1985	Spain	Almena
ILC 2555 (ICARDA)			1985	Spain	Alcazaba
ICCL 83110	(K 850 x T3) x (JG 62 x BEG 482)	Patancheru	1986	Kenya	ICCL 83110
ICC 552			1986	Myanmar	Yezin 1
ICC 4994			1986	Myanmar	Keyhman
ICC 4951			1986	Myanmar	Yezin 2
Selection from ICCX 730089	K 850 x F 378	Patancheru	1986	Myanmar	Schwe Kyehmon
ILC 482 (ICARDA)	ICC 11879		1986	Syria	Ghab 1
ILC 3279 (ICARDA)	ICC 19418		1986	Syria	Ghab 2
FLIP 83-46C (ICARDA)			1986	Tunisia	Kassab
Be-Sel-81-48 (ICARDA)			1986	Tunisia	Amdoun 1
ILC 3279 (ICARDA)	ICC 19418		1986	Tunisia	Chetoui
ICC 11879			1986	Turkey	
ICC 14911			1986	Turkey	
ILC 195 (ICARDA)	ICC 14911		1986	Turkey	ILC 195
ILC 482 (ICARDA)	ICC 11879		1986	Turkey	Guney Sarisi 482
ICCL 81248	P 481 x (JG 62 x P1630)	Patancheru	1987	Bangladesh	Nabin
ILC 464 (ICARDA)	ICC 17410		1987	Cyprus	Kyrenia

Continued

Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ILC 72 (ICARDA)	ICC 12961		1987	Italy	Califfo
ILC 3279 (ICARDA) - ICC 13816	ICC 19418		1987	Italy	Sultano
ICC 11879	ICC 11879		1987	Morocco	
ICC 14911			1987	Morocco	
ILC 195 (ICARDA)			1987	Morocco	ILC 195
ILC 482 (ICARDA)	ICC 11879		1987	Morocco	ILC 482
ICC 6098			1987	Nepal	Radha
ICCV 1	II 208 x T3		1987	Nepal	Sita
ILC 1335 (ICARDA) - ICC 8649			1987	Sudan	Shendi
ICC 11879			1988	Algeria	
ILC 482 (ICARDA)	ICC 11879		1988	Algeria	ILC 482
ILC 3279 (ICARDA)	ICC 19418		1988	Algeria	ILC 3279
ILC 202 (ICARDA)	ICC 11874		1988	China	ILC 202
ILC 411 (ICARDA)	ICC 18040		1988	China	ILC 411
ILC 482 (ICARDA)	ICC 11879		1988	France	TS 1009
FLIP 81-293C (ICARDA)			1988	France	TS 1502
ILC 237 (ICARDA)			1988	Oman	ILC 237
ILC 482 (ICARDA)	ICC 11879		1989	Lebanon	Janta 2
ILC 5566 (ICARDA)			1989	Portugal	Elmo
FLIP 85-17C (ICARDA)			1989	Portugal	Elvar
ILC 482 (ICARDA)	ICC 11879		1990	Jordan	Jubeiha 2
ILC 3279 (ICARDA)	ICC 19418		1990	Jordan	Jubeiha 3
ICCL 82108	(JG62 x WR 315) x (p 1363-1 x PRR 1)	Patancheru	1990	Nepal	Kalika
ICCC 32/ ICCV 6	L550 x L2	Patancheru	1990	Nepal	Koselee (K)
FLIP 85-7C (ICARDA)			1990	Turkey	Damla 89
FLIP 85-135C (ICARDA)			1990	Turkey	Tasova 89
FLIP 84-79 C (ICARDA)			1991	Algeria	FLIP 84-79 C
FLIP 84-92C (ICARDA)			1991	Algeria	FLIP 84-92C
Selection from ICCX-730167	JG 62 x F 496	Patancheru	1991	India	RSG 44
ILC 482 (ICARDA)	ICC 11879		1991	Iraq	ILC 482

Continued

Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ILC 3279 (ICARDA)	ICC 19418		1991	Iraq	ILC 3279
FLIP 84-92C (ICARDA)			1991	Morocco	FLIP 84-92C
FLIP 82-150 C (ICARDA)			1991	Syria	Ghab 3
FLIP 84-92C (ICARDA)			1991	Tunisia	FLIP 84-92 C
FLIP 84-79C (ICARDA)			1991	Tunisia	FLIP 84-79C
87AK 71115			1991	Turkey	Akcin
ICCV 10	P 1231 x P 1265	Patancheru	1992	India	Bharati (ICCV 10)
ICC 6304			1992	Portugal	ICC 6304
ICCV 10	P 1231 x P 1265	Patancheru	1993	Bangladesh	Barichhola - 2
ICCL 83105	(K 850 x T3) x (JG 62 x BEG 482)	Patancheru	1993	Bangladesh	Barichhola - 3
ICCL 82104	(Annegeri x Chaffa) x (Rabat x F 378)	Patancheru	1993	Ethiopia	Worku Golden
ICCV 2	[(K 850 x GW 5/7) x P458] x (L550x Guamuchal]	Patancheru	1993	India	Swetha (ICCV 2)
ICCL 79096	(JG62 x F 496)	Patancheru	1993	Pakistan	DG 92
ICC 4998			1994	Bangladesh	Bina-Sola 2
ICCV 92809	(BDN 9-3 x K 1184) x ICP 87440)	Patancheru	1994	USA	Myles
ICCL 82106	(P 99 x NEC 108) x Radhey	Patancheru	1995	Ethiopia	Akaki
ICCL 87207	K 850 x ICCL 80074	Patancheru	1995	India	Vishal
ICCL 85222	HMS 10 x (P 436 x H 223)	Patancheru	1996	Bangladesh	Barichhola - 4
ICCL 83149	(G 130 x B 108) x NP 34 x GW 5/7)	Patancheru	1996	Bangladesh	Barichhola- 6
ICC 14880			1997	Australia	Heera
ICCV 88202	PRR 1 x ICCC 1	Patancheru	1998	Australia	Sona
ICC 5035			1998	Portugal	Elite
ICCV 2	[(K 850 x GW 5/7) x P458] x (L550 x Guamuchal]	Patancheru	1998	Sudan	Wad Hamid (K)
ICCV 89509	(L550 x Radhey) x (K 850 x H 208)	Patancheru	1998	Sudan	Atmor (K)
ICCV 91302	ICCC32 x (K 4 x Chaffa)	Patancheru	1998	Sudan	Burgeig (K)

Continued

Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ICCV 92318	ICCC2 x Surutato 77) x ICC 7344)	Patancheru	1998	Sudan	Hawata (K)
ICC 3274			1999	Bangladesh	Barichhola - 7
ICCV 88003	(K 4 x Chaffa) x ICCL 81001)	Patancheru	1999	Bangladesh	Barichhola - 8 (K)
Selection from ICCX-820065	JG 1258 x BDN 9-3	Patancheru	1999	India	GG 2 (GCP 107)
ICCV 93958	ICCC 42 x ICC 12237	Patancheru	1999	India	CO 4
ICCV 93954	[(Phule G 5 x Narsinghpur bold) x ICCC 370) ICCX-860263-BF-BP-91-BP	Patancheru	1999	India	JG 11
ICCX-810800-3H-BW-1H-1H-BW	(GL 829 x ILC 202) selection from ICCX-810800-	Patancheru	1999	India	Himachal Chana 1
Selection from ICCX-840429	ICC C 32 x (Pant G-114 x GL 629)	Patancheru	1999	India	L 551
		Patancheru	1999	India	HPG 17
ICCV 92311	(ICCV 2 x Surutato 77) x ICC 7344	Patancheru	1999	India	PKV Kabuli 2 (KAK 2)
ICCV 93512	ICCC 33 x [L144 x E 100 Y (M)	Patancheru	2000	Ethiopia	Sasho (K)
Selection from ICCV 91106	Selection from G P ICCV - 91106	Patancheru	2000	India	Vaibhav
ICCV 89314	ICCL 80074 x ICCC 30	Patancheru	2000	India	Dilaji
Selection from ICCX-870105	ICCL 84224 x Annigeri	Patancheru	2000	India	GG4 (GCP 105)
ICCV 2	[(K 850 x GW 5/7) x P458] x (L550 x Guamuchal]	Patancheru	2000	Myanmar	Yezin 3 (K)
ICCV 88202	PRR1 x ICCC1	Patancheru	2000	Myanmar	Yezin 4
ICCC 37	P481 x (JG62 x P1630)	Patancheru	2001	India	Kranthi (ICCC 37)
ICCV 95418	ICC 7676 x ICCC 32) x (ICCC 49 x FLIP 82 - IC) X ICCV - 3)	Patancheru	2001	India	Virat
ICCV 96970	(ICCC 42 x ICCCV 88506) x (KPG 59 x JG74)	Patancheru	2001	India	JG 16
ICCV 94954	ICCC 42 x BG 256	Patancheru	2002	India	JG 130

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Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ICCV 95311	(ICCC 32 x ICCL 8004) x ICCC 49 XFLIP-82-8C) x ICCV 3	Patancheru	2002	India	Vihar (Phule G 95311)
ICCV 92337	(ICCV 2 x Surutato 77) x ICCV 7344)	Patancheru	2002	India	JGK 1
ICCV 90201	GL 769 x P 919	Patancheru	2003	India	Himachal Chana 2
	ICCV 2 x Surutato 77	Patancheru	2003	India	HK 98-155
ICCV 92318	(ICCV 2 x Surutato 77) x ICC 7344		2004	Ethiopia	Chefe
Selection from ICCX-860263	(Phule G-5 x Narsingpur Bold) x ICCC 37	Patancheru	2004	India	JG 412
ICCV 3	[(K 850 x GW 5/7) x P 458] x (L 550 x Guamuchil)		2004	Myanmar	Yezin 5
ICCV 92944	(GW 5/7 x P 326) x ICCL 83149	Patancheru	2004	Myanmar	Yezin 6
ICCV 96836	(BDN 9-3 x K 1184) x ICP 87440		2005	Australia	Genesis 836
ICCV 92033	Annigeri x ((Annigeri x ICC 506-EB) x (Annigeri x ICC 12237))	Patancheru	2005	Ethiopia	Kutaye
ICCV 88202	PAR 1 x ICCC 1	Patancheru	2005	India	Pratap Chana 1
Selection from (Annigeri x ICCV 6)	Derivative from cross of Annigeri x ICCV 6	Patancheru	2005	India	BDNG 797
ICCV 92006	(GW 5/7 x ICCC 37) x ICC 12271		2006	Ethiopia	Mastewal
ICCV 92069	(K 850 x JG 62) x [((Annigeri x (JG 62 x F 496)) x WR 315]		2006	Ethiopia	Fetenech
ICCV 14808		Patancheru	2006	Ethiopia	Yelbey (K)
ICCV 96329	(ICCL 81001 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	Patancheru	2006	India	L BeG 7
ICCV 95332	(ICC32 x L144) x ICCC 49 x FLIP 82-16C) x ICCV 3)	Patancheru	2006	India	JGK 2
ICCV 95334	[(ICCV 2 x Surutato 77) x ICC 7344] x Blanco Lechozo	Patancheru	2006	India	JGK 3 (JSC 19)

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Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ICCV2 x ICCV5	ICCV 2 x ICCV 5	Patancheru	2006	India	BGD 128
Selection from ICC X-910112-6	(ICCV 88102 x ICCV 10) x ICC 4958		2007	Ethiopia	Natoli
ICCV 93952	(ICCC 37 x GW 5/7) x ICCV 107	Patancheru	2007	India	JAKI 9218
ICCX-880203	(ICCV 10 x K 850) x (H 208 x RS 11)	Patancheru	2008	India	JG 6 (JSC 6)
ICCV 92944	[(GW5/7XP327) x ICCL 83149}	Patancheru	2008	India	JG 14
		Patancheru	2008	India	BGD103**
ICCX-840508-36	Dhanush x K 850		2008	Nepal	Tara
ICCV 96325	[(ICCV 2 x ICCV 88507) x ICCV 42} x ICC 7344	Patancheru	2009	India	IPCK 2004-29 (K)
		Patancheru	2009	India	KRIPA (K)
Chania Desi 1	ICCV 10 x GL 769	Patancheru	2009	Kenya	ICCV 97105
Saina K1	(ICC 7676 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	Patancheru	2009	Kenya	ICCV 95423
LDT 068	IG 9216 x ICCV 10	Patancheru	2009	Kenya	ICCV 00108 **
LDT 065	ICCV 5 x ICCL 83007	Patancheru	2009	Kenya	ICCV 00305**
			2009	Myanmar	Yezin 7
ICCV 97314	(ICCL 81001 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	Patancheru	2009	Myanmar	Yezin 8 (K)
ICCV 03107 (desi)	(ICCV 92065 x ICCV 88202) x KW 118		2010	Ethiopia	Minjar**
	Selection from local germplasm	Patancheru	2010	India	IPCK 02 (K)
	Selection from local germplasm	Patancheru	2010	India	MNK-1**
ICCV 95318 (Kabuli)	ICCV 2 x ICC 7344	Patancheru	2011	Bangladesh	Barichhola - 9 (K)
ICCV03402	GNG 1044 x [(L 550 x L 2) x Surutato 77]		2011	Ethiopia	Akuri

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Appendix 4. *Continued*

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
Sel. from ICCX-920215 (desi)	(ICCV 91902 x ICCV 10) x ICCV 89230	Patancheru	2011	India	RVG 101
		Patancheru	2011	India	RVG 201
ICCV 92944	(GW 5/7 x P 326) x ICCL 83149	Patancheru	2011	Kenya	ICCV 92944
ICCV 97126	ICCC 42 x ICCV 10		2011	Kenya	ICCV 97126
ICCV 00302			2011	Kenya	NPT
ICCV 00108 (desi)	IG 9216 x ICCV 10	Patancheru	2011	Tanzania	Mwanza 1**
ICCV 00305 (kabuli)	ICCV 5 x ICCL 83007	Patancheru	2011	Tanzania	Mwanza 2**
ICCV 92318 (Kabuli)	(ICCV 2 x Surutato 77) x ICC 7344		2011	Tanzania	Mwangaza**
ICCV 97105 (desi)	ICCV 10 x GL 769		2011	Tanzania	Ukiriguru 1**
		Patancheru	2012	India	RVG 203
Selection from Annigeri X ICC 4958	Annigeri x ICC 4958	Patancheru	2012	India	Nandhyala sanaga 1 (N BeG 3)
ICCX-000006	ICCV 2 x Bhawanipatna Local	Patancheru	2013	India	Birsa Chana 3
ICCV 97126	ICCC 42 x ICCV 10	Patancheru	2013	Kenya	Desi Chana 3

** Tropical Legumes-II project releases
ICC: ICRISAT Chickpea Collection
ICCV: ICRISAT Chickpea Variety
ICCC: ICRISAT Chickpea Cultivar
ICCL: ICRISAT Chickpea Line
ICCX: ICRISAT Chickpea Cross
ILC: ICARDA Legume Collection
FLIP: Food Legume Improvement Program of ICARDA

Source: ICRISAT Germplasm Unit and personal communication from BV Rao and Thimma Reddy

Appendix 5 Insights from focus group meetings (FGMs) and field observations.

Insights on the chickpea research domain

1. Chickpea requires cooler climates (< 35°C) and can only be grown in postrainy (rabi) conditions. Deep to medium or light textured black cotton soils are most suitable for cultivating chickpea as this crop grown in the postrainy season depends on the moisture remaining in the soil. Red, sandy and chalky soils are not found to be suitable for chickpea cultivation.

2. Since it is a postrainy season crop, the performance of chickpea is highly influenced by rainfall in that region. The distribution of rainfall also influences the productivity significantly. The annual average normal rainfall of the study districts ranges from 600 to 1000 mm. The highest normal rainfall was recorded in Nizamabad followed by Medak, Prakasam and Kadapa districts. The average normal rainfall for Kurnool and Mahabubnagar districts was around 600-650 mm. The lowest annual normal rainfall of 550 mm was observed in Anantapur district. It was observed that the risk of crop failure due to lack of moisture for the cultivation of chickpea was highest in Anantapur districts, followed by Kurnool and Mahabubnagar.

Cropping system in AP

3. Chickpea is mostly grown as a sole crop in Andhra Pradesh. It was observed to be used as inter-crop only in Medak district (with safflower in 9:1 ratio).

4. Crops such as sorghum, tobacco, groundnut, redgram, cotton, coriander and sunflower were dominant crops during 1990s in most of the mandals and study districts. Through the years, chickpea has replaced these crops because of the following reasons:

    a) The new chickpea cultivars provided a short-duration crop
    b) Chickpea cultivation is less-labor intensive
    c) Relatively low investment per acre is needed
    d) Viewed as a less risky crop
    e) Assured yields, market and good remunerative price of chickpea crop
    f) Highly suitable for mechanical operations
    g) Lower pest problem
    h) Improves soil fertility
    i) Can easily cultivate on a large scale

Farm size and land utilization

5. A large proportion of the farmers in the 90 study villages are chickpea growers with plot areas ranging from very small (about 1 acre) to very large (about 100 acres). The remaining farmers who are not growing chickpea in these villages indicated that they are not growing chickpea because the soils were not suitable (eg, red, sandy and chalky soils) or lack of access to irrigation facilities.

    So, based on a random sample of 90 villages representing current chickpea farmers, the following questions may be resolved: Has the ceiling level of adoption been reached? How much of the vertisols is currently covered? Are there other factors that must be considered which determine the limits of the chickpea crop production in Andhra Pradesh (for example, irrigation)? Or other factors explain other crop diversification options? GIS may estimate % of cropped area is vertisols; vertisols/unirrigated – which may be the potential boundary of applicability. Or other variables may be realized to explain why the maximum possible adoption level has actually been reached.

6. Initial results show that while nearly 55% of the total cultivable area in these villages is under chickpea cultivation (and the rest of the area remains under traditional crops – cotton, sorghum, groundnut, tobacco, soybean, paddy etc.), it is noteworthy that about 72% of total black soil (vertisols) area in the study villages covered is now grown to chickpea.
7. The chickpea cropped area in the sample villages was found to increase nearly seven times between 1997 and 2002. This expanded nearly four times during the period 2003 and 2007. After this period of rapid expansion, chickpea area further doubled in later years (from 2008 to 2011).
8. The average land holding sizes of chickpea growers were found to be much higher in Prakasam and Kurnool districts (15-20 acres), followed by Kadapa (10-12 acres) and Anantapur (5-8 acres) districts.
9. In most of the mandals, the area under chickpea was very low even up to the late 1990s. Adoption of chickpea as a crop through the introduction of short-duration improved varieties picked up significantly since early 2000s. Phenomenal increase in area was observed after access was made available to the variety JG 11 and its distribution was facilitated by the Agricultural Department. Much of the awareness regarding this variety escalated from 2004.
10. In general, farmers in most of the study districts were found to be knowledgeable about improved cultivars of chickpea and their features. Nearly 80% of the farmers knew which cultivar they were growing. However, in two districts – Medak and Nizamabad – awareness of improved cultivars was found to be very low.
11. During the survey implementation, the experimentation of the 'Varietal Identification Protocol' actually facilitated the process of providing accurate information about specific varietal adoption and other related information.
12. Up to the late '90s, most farmers used to grow a chickpea variety called Annigeri (released in 1978). Farmers reportd an average yield of 725 to 967 kg per ha. However since shifting to JG 11 and other improved cultivars, average yields increased to 1450 to 1934 kg per ha. In some mandals, the best yields recorded were as high as 2417 to 2900 kg per ha under favorable climatic conditions.
13. The two major desirable traits of JG 11 reported by farmers in contrast to Annigeri are: higher productivity and wilt resistance.
14. Based on the focus group meetings, it seems that a very large proportion of the chickpea area is under improved cultivars. The most progressive of them all, Prakasam district, is dominated by kabuli varieties (around 60%) while the rest of the district's chickpea growing area is planted to JG 11 (desi type). The older variety Annigeri was found in villages of Nizamabad and Medak districts.
15. By and large, the survey team reckons that nearly 85% of chickpea area in the whole state is under JG 11. It is the single largest variety occupying major proportion of chickpea area across different districts. JG 11 is followed by KAK 2, Vihar, Dollar or Bolt, JAKI 9218 and N Beg 3, in that order.
16. It is observed that about 50-60% of seed requirement of the farmers in the villages is met by their own sources and the remaining 30-40% is procured from market sources. Most farmers procure seeds from the Department of Agriculture or from farmers and traders from other locations.
17. Most farmers buy new seed only once in three years.

18. Chickpea productivity per ha has nearly doubled after the introduction of short-duration improved cultivars.
19. The average chickpea yields in the state are 1450 to 1934 kg per ha and vary across districts. The highest yields were observed in Prakasam district – ranging from 2175 to 2900 kg per ha. The average yield levels were only 967 to 1209 kg per ha in Kurnool and Anantapur districts because of the drought during 2011-12. Between these two extremes, the yields in the Nandyal region of Kurnool and Kadapa districts were between 1692 and 2175 kg per ha. The impact of drought was obvious as reflected in chickpea yields during the 2011-12 drought-stricken rabi season.
20. The farmers' average expectation of yield was 2417 kg per ha. They also anticipate a market price of Rs 50 per kg. As long as these conditions on yield and price are met, farmers indicate that they will continue to grow the chickpea crop. Otherwise, they will look for alternative crops such as maize, foxtail millet and Azwan among alternative options.

Summary on demographics

21. The size of the average farm family in the study districts is between 4 and 6. More joint families were observed in Kurnool district when compared to other study districts. Each family has a maximum of two members participating in agricultural activity.
22. Use of bullocks in crop cultivation has reduced significantly. Mechanization (usage of tractors) has increased in agriculture right from the stage of land preparation to threshing and transportation. With increasing labor scarcity, wage rates have gone up enormously during the last five years.
23. Most farmers depended on formal sources of credit for cultivation in sample districts. In contrast, they tended to rely more on the informal sector till a decade ago.

Insights on some dimensions of outcomes and impacts

24. The impact of short-duration chickpea technology on farmers' welfare, especially after the introduction of JG 11 is initially assessed qualitatively. Most farmers averred that they are better off now when compared to ten years ago. Renovating of houses, children's education, their weddings, purchase of land and gold among other things were reported to be some of the investments made by them as a result of increased income from chickpea in the last decade.
25. There is no regulated market for chickpea in Andhra Pradesh. As a consequence, most of the sample farmers reported that they sell their output to middlemen or traders within the villages. But in the more progressive districts of Prakasam and part of Kurnool where farmers have good access to cold storage facilities, they are able to avoid distress sales and are able to benefit from more remunerative prices.
26. With the chickpea revolution brewing in the chickpea growing districts of AP, the leased-in land values have gone up very significantly. These values were highest in Prakasam followed by Kurnool.
27. The role of women in chickpea cultivation is critical especially during sowing, weeding and harvesting operations. However, because of increased mechanization, their role has been gradually diminished.
28. When asked for the traits they would like to see in improved cultivars of chickpea in the future, respondent farmers clearly mention the following:
    - high yielding with drought and mid-season fog resistant types
    - tall & erect plant types with mechanical harvestable cultivars

- disease resistant particularly for dry root rot and wilt
- high fodder quality types which are more suitable to animal feeding

29. To sustain the chickpea area in the state and study regions, farmers suggested the following additional requirements:
    - More drought resistant cultivars yielding around 2417 kg per ha
    - Stable market price is important, noting the price decline during 2012-13
    - Coverage of crop insurance for chickpea
    - Control of wild pigs and deer
    - Better storage and value addition facilities for chickpea
30. The farmers in the study districts showed their willingness to pay more for seeds over the base price if the new cultivars have the desired traits. This premium price ranges from 25-50% more per kg of seeds based on specific desired traits.

Appendix 6. Decision tree protocol for identification of chickpea cultivars.

Farmer name: .... Village:.................................... ID no.: ....

(Note: If farmer is growing both *desi* and kabuli types, fill two forms separately for *desi* and kabuli types. After identification of variety, pl. round-off the name of variety)

1. Type of chickpea variety: Local, desi and kabuli?	
No.	Question
1	Which chickpea variety did you grow last year? ....
2	2.1. Which type of chickpea variety was it (desi/kabuli)? .... 2.2. What was the flower color of the variety (white/purple)? .... 2.3. What was the seed coat color (yellowish brown/white)? .... 2.4. What was the foliage colour (dark green/light green)? .... 2.5. What was the plant type (erect/bushy)? ....
3	3.1. If answers are **white** seeded, **erect** plant type with **light green** foliage and **white** flowers → CLASSIFY as **KABULI** variety and go to **QUESTION 4** 3.2. If answers are **yellowish brown** seeded**,** bushy plant type with dark green foliage and purple flowers → CLASSIFY as **DESI** variety and go to **QUESTION 5**
4	Does the cultivar feature: short-duration (95-110 days), spreading, large-sized, owl-headed seeds? IF **YES**, → CLASSIFY as **KAK 2 variety** (no more questions) IF **NO** → CLASSIFY as **VIHAR** (if it has medium maturity (105 to 110 days), little upright, medium-sized seeds) **Otherwise**→ CLASSIFY as **Dollar (Bold non-descriptive)** (if it has **extra large** size seeds)
5	How long you have been growing this **desi chickpea variety**? (> 10 years / < 10 years) IF ANSWER is > 10 years → CLASSIFY as **ANNEGIRI** variety (no more questions) IF ANSWER is < 10 years, go to QUESTION 6

2. Which improved desi variety of chickpea?

No.	Question
6	Does the crop mature in < 100 days, have pink flowers and less angular seeds? (Yes/No) If YES → variety may be JG 11 or Kranthi go to QUESTION 7 If NO, SKIP to QUESTION 8
7	Does the plant have more basal branches, erect and weak purple pigmentation? (Yes/No) IF YES, the variety is JG 11 (ICCV 93954) IF NO, the variety is Kranthi (ICCC 37)

8	Does this variety take > 110 days to mature, semi-spreading and seeds are more angular? (Yes/No) If answer is YES, the variety is JAKI 9218 If answer is NO, go to QUESTION 9
9	If this sequence doesn't follow, ie, they are non-descriptive type → (VISHAL or CHAFFA)

Appendix 7. Household survey questionnaire, 2011-12.

Particulars	Answers		CODE/ID
Name			
S/o or D/o or W/o			
Village			
Mandal			
District			
State			
Mobile			
GPS reading of HH	LAT (N):		LONG (E):
Is this HH (tick)	TCF	MCF	SCF

TCF: Traditional chickpea grower MCF: Modern chickpea grower SCF: Switcher chickpea grower

1.1 Household Information

Main occupation: ----------------------------------- Subsidiary occupation: -------------------------------------

Caste category: ---------------------------- (SC/ST/BC/OC)

No. of years of farming: ---------------------- No. of years of chickpea growing: ----------------------- (Yrs)

1.2 Family composition

Name	Relation with head	Sex (M/F)	Age (Yr)	Education (Yr)	Working in (Y/N)	
					Own-farm	Labor market

1.3 Landholding details in 2011-12 cropping year (acres)

Type	Owned	Leased/shared-in	Leased/shared-out	Permanent sallow/grazing land	Operated
Wetland					
Dryland					
Total					

Operational land: (Owned + leased/shared-in) – (leased-out/shared-out + permanent fallow/grazing land)

1.4 Cropping pattern (details of CY 2011-12Kharif crops in acres)

Plot name	Owner ship*	Plot area (acres)	Name of the crop	Proportion	Variety**	Specify name	Cropped area	Irrigated area	Main Production (Kg)	Price/ kg	By-product (qt)	Price/qt

1.5 Cropping pattern (details of cropping year 2011-12; rabi crops in acres)

Plot name	Ownership*	Plot area (acres)	Name of the crop	Proportion	Variety**	Specify name	Cropped area	Irrigated area	Main production (kg)	Price/ kg	By-product (qt)	Price/qt

* Use codes: Own land (OW), leased-in (LI), leased-out (LO), shared-in (SI) and shared-out (SO)
** 1. Local; 2. Improved; 3. Hybrid

1.6 Details of household assets (as on July 2012)			
Resources	Quantity	Unit price	Total value
1.1. LAND (acres)			
1. Dryland			
2. Irrigated land			
3. Grazing/Fallow land			
1.2 LIVESTOCK (number)			
1. Draft animals			
2. She buffaloes			
3. Cows			
4. Young cattle			
5. Goats/sheep			
6. Others (specify)			
1.3. FARM EQUIPMENT (number)			
1. Tractor with attachments			
2. Threshers/power tillers			
3. Electric motors/oil engines			
4. Sprinkler sets/drip irrigation			
5. Submersible pump sets			
6. Power or manual sprayer/duster			
7. Modern plough/seed drill/disc harrow etc.			
8. Other tools and implements			
9. Others if any			
1.4. FARM BUILDING (sq. yard)			
1. Residential house including courtyard			
2. Farm house including cattle shed			
3. Residential plots (if any)			
4. Others (specify-------------------------)			
1.5. CONSUMER DURABLES			
1. Gold and silver			
2. Auto/two-wheelers			
3. Fridge/television/washing machine			
4. Mobile/fan/radio/tape recorder etc.			
5. Cooking gas (LPG)			
6. Mobile phones			
7. Others (specify ------------------------)			

2. Adoption of improved cultivars of chickpea

2.1. In general, what is your choice of cultivar in chickpea cultivation --------------- (local/improved)

2.2. Reasons: ---

2.3. First adoption of improved chickpea cultivars and sources of seed

								First seed details			Adoption in 2011-12		Future Adoption	
Crop (codes A)	Improved varieties Known Use Annex	Year variety was known first	Main source of variety information (Codes B)	Ever planted? (Codes C)	If NO, Why? (Codes D)	If YES, year first planted	Area first planted (acres)	Main source of first seed (Codes F)	Quantity of first seed (kg)	Means of acquiring first seed (Codes E)	Planted variety in 2011/12 season? (Codes C)	If NO in 2011/12 why? (Codes D)	Will you plant the variety in 2012-13? (Codes c)	If No, why? (Codes D)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Codes A	Codes B	Codes C	Codes D	Codes F	Codes E
Chickpea	1. Govt. extension	1. Yes	1. Didn't get seed	1. Research PVS	1. Gift/Free
	2. Farmer association	2. No	2.Lack of cash to buy	2. Extension demo plots	2. Borrowed seed
	3. NGO		3. Diseases and pests	3. Farmer club	3. Bought with cash
	4. Research centre		4. Poor taste	4. Local seed producers	4. Payment in kind
	5. On-farm trials/demos		5. Low yielding	5. Local trader or agro-dealers	5. Exchange with other seeds
	6. Fellow farmer		6. Require more rainfall	6. Farmer to farmer seed exchange (relative, friend etc.)	6. Others -------------
	7. Private shop		7. Expensive seed cost	7. NGOs	
	8. Newspaper/radio/TV		8. No market	8. Govt agency	
	9. Others --------		9. Poor price	9. Inherited from family	
			10. Others -----------	10. Villagers	
				11. Other (specify)......	

2.4 How often do you grow chickpea on same land (crop rotation)? (……………….)

(a) Every year (b) Once in two years (c) Once in three years (d) Others (specify) ....

2.5 Area allocation under chickpea during the last three years? --------------------------- (I/D/C)

2.6 What are the crops replaced by chickpea, if the area is increasing?

(a) -------------------- (b) --------------------- (c) --------------------------

2.7 Which year did you switch from other crops to chickpea? ------------------------- (Year)

2.8 What are the crops replacing chickpea crop, if the area is decreasing?

(a) -------------------- (b) --------------------- (c) --------------------------

2.9 Which year did you re-switch from chickpea to other crops? ---------------------------- (Year)

2.10 Is chickpea crop grown as sole crop or inter-crop? --- (if inter-crop, specify: ---------------------)

2.11 Sources of seeds in 2011-12 planting (major three crops including chickpea)

Crop	Variety	Source 1	Source 2	Source 3
Chickpea				
Crop 2				
Crop 3				

1. Research PVS	5. Bought from villagers	9. Seed dealer
2. Extension demo plots	6. Farmer to farmer seed exchange (relative, friend, etc.)	10. Subsidized government seed scheme
3. Farmer club	7. Provided free by NGOs	11. Other (specify) ……………………….
4. Own seed	8. Provided free by govt. agency	

2.12 Allocation of chickpea area under different cultivars/varieties in the last three years?

	Area chickpea sown in acres		
Cultivars	Area in 2011-12	Area in 2010-11	Area in 2009-10
1.			
2.			
3.			
4.			
5.			

2.13 Varietal replacement during last five years (2007-2011)

1. How many new cultivars did you introduce/test?
2. What is the main source for those new cultivars (for codes, refer above)
3. How many times did you buy seed from market (out of five years)
4. What is your preferred source of borrowing seed (for codes, refer above)

2.14 Average chickpea yield harvest by this household (kgs/acre)			
Year	Variety 1: ……………..	Variety 2: ………………..	Variety 3: …………………
Normal year			
Bad year			
Best yield recorded so far			

3. 1 Awareness and adoption of natural resource management (NRM) technologies in chickpea cultivation

Can you provide the details of plot-level soil characteristics? (Plot details should match with cropping pattern module)

Plot name	Crop name	Soil type	Soil depth	Soil slope	Soil fertility	Risk of soil erosion	Soil degradation problems

Soil type	**Soil depth**	**Soil slope**	**Soil fertility**	**Risk of soil** erosion	**Soil degradation**
Black = 1 Alluvial = 2 Sandy = 3 Red soil = 4	Shallow = 1 Medium = 2 Deep = 3 Very deep = 4	Levelled = 1 Gentle slope = 2 Medium slope = 3 High slope = 4	Very poor (not used) = 1 Poor = 2 Good = 3 Very good = 4	No risk = 1 Low risk = 2 Medium = 3 High risk = 4	No problem = 1 Soil erosion = 2 Nutrient depletion = 3 Water logging = 4 Salinity/alkalinity = 5 Acidity = 6

3.2 Does the household practice the following NRM technologies since 2000?

Method	Practice (Y = 1/ N = 2)	When started (Year)	Total costs incurred so far (Rs)	Specify your share (Rs)	Investment during the three years (Rs)	Specify the crop grown in that plot
Soil or stone bunds						
Field/boundary bunds						
Biological barriers						
Broad bed and furrow						
Land levelling						
Check dams						
Farm ponds						
Contour bunding						
Others						

3.3. What is specific contribution of this technology in chickpea cultivation?

a. ---

b. ---

c. ---

4.1 Role of networks in technology adoption

Is this household a member of any social network? --------------------------- (Y/N)

If yes, network type	Member in (tick)	Which network does this HH use to share/acquire information about new seeds/ NRM technologies (tick)	How frequently does this group meet in three months (no.)	Sources of information for network (code)	In which network do you have more faith (tick)
SHGs					
Rythu-mitra					
Cooperative					
Farmer club					
Caste group					
Relative					
Friends/ villagers					
Panchayat					

If HH is not a member in any social networks, reasons?

4.2 Crop utilization (three major crops including chickpea)

			Utilisation of product					
Crop (codes)	Variety	Total production (kg)	Saved as seed (kg)	Gift/kind payments (kg)	Consumed as food/feed (kg)	Paid as land rent (kg)	Sold in market (kg)	In store (kg)
1								

Code A: 1 = Chickpea; 2 = ...; 3 = ...

4.3 Marketing of crop production (refer three major crops including chickpea)

Total chickpea production during the year: ------------------------- qtls

Crop code	Market type (Codes A)	Marketing cost (Rs/qtl)					Cold storage cost (Rs/qtl)	Sold as (qtl)		Price (Rs/ qtls)	
		Bagging	Trans-port	Commi-ssion agent	Market fee	Hamali (labor)		grain	seed	grain	seed

Codes A: Village market = 1, Weekly market = 2, Regulated market = 3, Others = 4

5. Sources of information (Rank three major sources)

Issue	Chickpea			Crop 2			Crop 3		
	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
1. New varieties of crops									
2. Crop pest and disease control									
3. Output markets and prices									
4. Input markets and prices									
5. Weather forecasting									
6. Soil and water conservation									

1. Government extension agent
2. Research centre
3. Newspaper
4. Seed traders/Agro-dealer
5. Other private shops
6. Radio/TV
7. Mobile phone
8. Neighbour/other farmers
9. NGOs
10. Farmer clubs/associations
11. Market
12. Other (specify) ....

6. Source of credit for chickpea cultivation during 2011-12 (need and access)

Purposes for borrowing	Needed credit? (Codes A)	If YES, did you get it (Codes A)	If you did not get credit, why? Rank 2 (Codes B)	Did you get the required amount (Codes A)	If you got credit: Source of credit (Codes C)	Amount Received (₹)	Interest rate (%)	Month borrowed (1-12)
1	2	3	4	5	6	7	8	9
1. Buying seeds								
2. Buying fertilizer								
3. Buy pesticides								
4. Hiring farm equipment/ labour								
5. Buying livestock								
6. Adopting soil and water conservation								
Others								

Codes A
1. Yes
0. No

Codes B
1. Borrowing is risky
2. Interest rate is too high
3. Too much paperwork
4. Does not know application procedures
5. No lenders in this area for this purpose
6. Lenders do not provide the amount needed
7. Other (specify) ....

Codes C
1. Commercial banks
2. Cooperatives (PACS)
3. Micro-finance
4. Money lender
5. Relatives/friends
7. Farmer club/self help groups
8. Input dealer
9. Other (specify) ....

7. Major sources of household (Rs) (net income from July 2011 to June 2012 only)	
Sources of income	Net income (Rs)
1. Income from crops including orchards	
2. Farm work (labor earnings)	
3. Non-farm work (labor earnings)	
4. Regular farm servant (RFS)	
5. Livestock (milk and milk products selling)	
6. Income from hiring out bullocks	
7. Income from selling sheep, goat, chicken, meat, eggs etc.	
8. Selling of water for agriculture purpose	
9. Selling common-pool resources (firewood, fruits, stones and mats etc.)	
10. Selling handicrafts (specify)	
11. Rental income (tractor, auto, sprayer and truck etc.)	
12. Rent from land, building and machinery etc.	
13. Caste occupations (specify)	
14. Business (specify)	
15. Regular salaried jobs (govt./private)	
16. Out migration	
17. Remittances	
18. Interest on savings and from money lending	
19. Cash and kind gifts including dowry received	
20. Pension from employer	
21. Government welfare/development programs	
22. Others 1	
23. Others 2	

8. Household consumption expenditure (from July 2011 to June 2012)				
Total members in the household consuming food (adults) ----------- (children >12 years) --------				
Item	Code** D/W/M/Y	Average quantity consumed kg or litre	Average unit price (Rs)	Total value (Rs)
FOOD EXPENDITURE				
Rice				
Wheat				
Other cereals				
Pigeonpea				
Chickpea				
Green gram				
Black gram				
Other pulses				
Milk				
Other milk products				
Cooking oil				
Groundnut kernels				
Non-veg (chicken, mutton, beef, fish, eggs etc.)				
Fruits				
Vegetables				
Tea, coffee, sugar & gur				
All spices				
Processed food items & hotel expenses				
Other food items				
NON-FOOD EXPENDITURE				
Health expenditure				
Education/stationery				
Clothing/shoes				
Entertainment/travel/vehicle				
Ceremonies				
Toddy & alcohol				
Cosmetics (hair oil, soaps etc.)				
Taxes/maintenance				
Pan, beedi, cigarettes etc.				
Cooking fuel/ LPG				
Phone/mobile bill				
Others				

**D = day, W = week, M = month and Y = year

9. Perceptions about farm-level chickpea and NRM technology benefits

9.1 Do the improved technologies benefit in any way? .... (Y/N) If no, go to section 9.3

If yes, please provide the following information:

Type of benefit	Chickpea technologies		NRM technologies	
	Benefitted (Yes/No)	Extent of benefit (%)	Benefitted (Yes/No)	Extent of benefit (%)
Increase grain yield				
Increased fodder yield				
Reduced cost of cultivation/qtl				
Increased net returns per acre				
Better grain quality				
Better fodder quality				
Reduced the duration				
Resistant to pests and diseases*				
Resistant to drought*				
Improved soil condition*				
Reduced the crop risk				
Increased mechanization (cost/acre)				
Increased gender participation/acre				
Others				

* Information to be gathered in terms of yield per acre

9.2 After having benefitted from these technologies, would you like to continue using these technologies in the future? ----------------- (Y/N)

If no, why: ----------------------------- ---------------------------- ----------------------

If yes, has the adoption of these technologies changed input-use behaviour ---------- (Y/N)

If yes (already changed behaviour) go to a. Otherwise go to b (planning to change).

a). If yes, how did you allocate various inputs in chickpea cultivation?

Input allocation	When changed (year)	Old allocation	Revised allocation
Own land allocation (acres)			
Leased-in land allocation (acres)			
Mechanization (Rs/acre)			
Fertilizer application cost (Rs/acre)			
Pesticide application cost (Rs/acre)			
Irrigation expenditure (Rs/acre)			
Soil & water conservation expenditure (Rs/acre)			
Others			

b. If No, how are you planning to change the allocation for chickpea cultivation?

Input allocation	When will you start (year)	Present allocation	Future allocation
Own land allocation (acres)			
Leased-in land allocation (acres)			
Mechanization (Rs/acre)			
Fertilizer application cost (Rs/acre)			
Pesticide application cost (Rs/acre)			
Irrigation expenditure (Rs/acre)			
Soil & water conservation expenditure (Rs/acre)			
Others			

9.3. If the household has not benefitted from any technology, specify the problems/constraints encountered in implementing them? (List three)

a). --

b). --

c). --

9.4. List out the limitations in expanding adoption under these technologies? (List three)

a). --

b). --

c). --

9.5. What are the important traits you are looking for in new chickpea cultivars (List three)

a). --

b). --

c). --

9.6. Any other feedback or suggestions for the promotion of these technologies (List three)

a). --

b). --

c).---

Investigator name: ----------------------------------- Remarks if any: ---

(Input-output module will be added for collecting cost of cultivation (COC) data for one-third of the sample covering all crops).

Cost of cultivation module

ID no. --

Study crop name: --------------------- Variety: ------------------- Plot size: ------------------ Season: ------------

Sole/inter-crop: -- (if intercrop, ratio: -----------------------------------)

		Labor use[1]			Input/Output		
Operations		Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
1A. Land preparation (Ploughing primary and secondary tillage)	M	Days					
	F	Days					
	B	Days					
	T	Hours					
1B. Seedbed preparation	M	Days					
[Broad bed furrow (BBF)/Narrow Border Flood (NBF)/flat]	F	Days					
	B	Days					
	T	Hours					
2. Farm yard manure/Compost/ Sheep penning/Tank silt application	M	Days					
	F	Days					
	B	Days					
	T	Hour					
FYM/Compost/poultry		Quintal					
Animal penning		Number					
Date of sowing							
3. Planting/sowing	M	Days					
	F	Days					
	B	Days					
	T	Hours					
4 A. Seed: Crop code		Kg					
Crop code		Kg					
Crop code		Kg					
4B. Seed treatment	M	Days					
	F	Days					
------------------		Kg					
------------------		Liter					

Operations		Labor use[1]			Input/Output		
		Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
5A. Fertilizer application	M	Days					
	F	Days					
--------------------------		Kg					
-------------------------		Kg					
--------------------------		Kg					
--------------------------		Kg					
5B. Micronutrient application	M	Days					
	F	Days					
----------------------		Kg					
----------------------		Kg					
6. Interculture	M	Days					
	F	Days					
	B	Days					
	T	Hours					
7. Weeding/Weedicide application	M	Days					
	F	Days					
	SP	Hours					
Type (sprayer/duster/other)	T	Hours					
------------------------		Liter					
------------------------		Liter					
8. Plant protection (Spraying/dusting/shaking /hand picking pests)	M	Days					
	F	Days					
	B	Days					
	T	Hours					
Type (sprayer/duster/other)	SP	Hours					
	DU	Kg					

---------------------							
9. Irrigation	M	Days					
	F	Days					
	ME	Hours					

Operations		Labor use[1]			Input/Output		
		Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
Source of Irrigation							
10. Watching (Birds, Pigs etc.,)	M	Days					
	F	Days					
Date of harvesting main crop							
11. Harvesting[2]: Crop code.......	M	Days					
	F	Days					
Crop code.....................	M	Days					
	F	Days					
Crop code....................	M	Days					
	F	Days					
12. Threshing and cleaning Crop code......	M	Days					
	F	Days					
	B	Days					
	TH	Hours					
Crop code..........	M	Days					
	F	Days					
	B	Days					
	TH	Hours					
Crop code.............	M	Days					
	F	Days					
	B	Days					
	TH	Hours					
13. Marketing (including transport and storage)	M	Days					
	F	Days					
	B	Days					
	T	Hours					
14. Fixed Cost: Land Rent (per acre) Cash		Rs					
Kind		Kg					
Land tax (per acre)		Rs					

	Labor use[1]			Input/Output		
Operations	Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
15. Grain Yield:						
Crop code.........	Kg					
Crop code..........	Kg					
Crop code..........	Kg					
	Kg					
16. Fodder yield:						
Crop code..........	Quintal					
Crop code.........	Quintal					
Crop code.........	Quintal					
	Quintal					
	Quintal					
17. Stalk: -------- Crop code...........	Quintal					
---------------- Crop code...........	Quintal					

[1] Labor input includes total labor days of family and hired labor for each operation. Specify male and female labor as well as bullock labor separately wherever necessary.

[2] Estimate the labor requirement hired contractor for harvesting.

Note: Clearly specify the units (eg, 5 kgs, FYM = 2 qtls etc).

M = Male labor, F = Female labor, B = Bullock pair labor,

T = Tractor/Truck, TH = Thresher, SP = Sprayer, DU = Duster.

Note: Irrigation (Open dugwell, borewell, submersible pump, tank, canal and others (specify) ---------

Note: Cost of hiring tractors\bullocks pair includes cost of operator.

Note: Ask\calculate land rent (Rs/acre) for that particular crop.

Appendix 8. Village survey questionnaire, 2011-12.

1. Village particulars

Village name Code:

Mandal name

District name

State name

Avg. Rainfall (mm)

GPS readings Lat (N): Long (E):

2. Main respondent details

Main respondent's name

S/o or D/o or W/o

Position in the village

Major occupation

Mobile no:

3. General particulars of village

Total population of the village

No. of households

Total no. of cultivators/farmers

No. of chickpea cultivators/farmers

Average land holding size (acres)

Total geographical area of village (acres)

Area under cultivation (acres)

Area under irrigation (acres)

Distance to regulated market (km)

Distance to storage facility (km)

Distance to agricultural research station (km)

Distance to agriculture office (km)

Distance to input shop (km)

4. Cropping pattern details (2011-12; acres)

Kharif major crops	Area	Rabi major crops	Area	Summer major crops	Area

5. Major sources of irrigation and soil types					
Source	Area (acres)	% cropped area	Soil type	Area (acres)	% cropped area
Tanks					
Canals					
Open dug wells					
Borewells					
Others					

6. Area under chickpea over the last one and half decade (1997-2012)				
Year	1997	2002	2007	2011
Area in acres				

7. Major cultivars in chickpea cultivation							
Year 2011		Year 2007		Year 2002		Year 1997	
Cultivar name	% area	Cultivar name	% area	Cultivar name	% area	Cultivar name	% area

8. Reasons for preference of cultivars during 2011-12		
Cultivar name	Reason for preference 1	Reason for preference 2

9. Pattern of varietal replacement in chickpea during last one decade (2001-11) (write in box)

10. Major sources of seed supply for chickpea in the village		
Major cultivar name	Major supplier of seed 1	Major supplier of seed 2

11. Performance of chickpea yields (kg per acre) during 2010-11 and 2011-12						
Year	Variety 1:		Variety 2:		Variety 3:	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Normal yield						
Bad yield						
Best yield so far						

12. Major constraints for chickpea in the village	
a. Biotic constraints	b. Abiotic constraints
1.	1.
2.	2.
3.	3.
4.	4.

13. What are the major competing crops for chickpea in the village?	
Competing crop	What is the advantage of the competing crop over chickpea
	1.
	2.
	1.
	2.

14. Market price for chickpea over the last one and half decade (1997-2011)				
Year	1997	2002	2007	2011
Desi (price/qtl)				
Kabuli (price/qtl)				

15. Any value-addition practices followed for chickpea in the village ---------------------- (Y/N) If yes, what are they:

1.--

2.--

3.--

16. How did you perceive the difference between the new and old chickpea cultivars?				
	Ranking of variety			
Characteristics	Chickpea desi*		Chickpea kabuli*	
Variety name				
1. Production traits				
High-yield				
Short-duration				
Drought-tolerance				
Heat-tolerance				
Pod bore-resistance				
Disease-resistance				
Fit into existing cropping system				
2. Consumption traits				
Better taste				
Less cooking time				
Others				
3. Marketing traits				
High demand				
Fetches higher price				
Low price fluctuations				
Others				
Overall variety score				
* Codes: 1 = Poor, 2 = Average, 3 = Good, 4 =Same, 5 = Low, 6 = High, 7 = Short, 8 = Long				

17. Cultivar-wise constraints (Please tick across specific constraints)				
	Chickpea desi		Chickpea kabuli	
CONSTRAINTS	Variety name		Variety name	
Low yield				
High pod borer incidence				
High disease incidence				
Long duration				
Small grain size				
Not attractive color				
Poor taste				
Low recovery of dal (%)				
Low market price				
Not fitting into cropping system				
Poor fodder quality				
Susceptible to storage pest				

18. Subsidies and benefits accrued from government for growing chickpea crop (2011-12)			
Inputs/outputs	Name of program	Extent of benefits (in Rs/acre)	Extent of benefits (in kind if any/acre)
Seeds			
Credit			
Fertilizers			
Pesticides			
NRM activities			
Water exploration			
Output prices			
Others			

19. How have new chickpea cultivars benefitted farmers? (Perceptions)		
Quantitative parameter	Before the adoption of new cultivars (year.............)	After adoption of new cultivars in 2011-12
1. Yield (kgs/acre)		
2. Net income per acre of chickpea (Rs)		
3. Cost per acre (Rs)		
4. Pesticide application per acre (Rs)		
5. Fertilizer application per acre (Rs)		
6. Labor cost per acre (Rs)		
7. Unit price of output (Rs)		
8. Mechanization cost per acre (Rs)		
9. Rental value of land per acre (Rs)		
Qualitative parameter	Before the adoption of new cultivars (year.............)	After adoption of new cultivars in 2011-12
1. Risk in agriculture (H/S/L)		
2. Better fit to cropping system (Y/N)		
3. Improved soil fertility (H/S/L)		
4. Loan repaying capacity (H/S/L)		
5. Savings per average farm (H/S/L)		
6. Improved nutrition of HH (H/S/L)		
7. Gender empowerment (H/S/L)		
H = High; S = Same; L = Low		

20. Village infrastructure details		
Item	(Yes/No)	Distance
Good road to nearest town (km)		
Storage facility (M tons)		
Cold storage facility (M tons)		
Good communication system (no. of mobiles)		
Internet connections (nos)		

21. Village lending system		
Major source	% farmers benefitted	% share in total lending requirement
1. Govt. banks		
2. Cooperatives		
3. Private banks		
4. Money lenders		
5. Input dealers/Shops		
6. Friends/relatives		
7. Others		

22. Types of traits farmer is looking for in new chickpea cultivars?

a. --

b.--

c.--

23. Willingness to pay more for improved seeds (over existing base price of seed)	
Cultivar type	% over base price
Cultivar suitable for mechanical harvesting	
Cultivar with herbicide-resistance	
Cultivar with root rot disease resistance	
Cultivar with heat tolerance	
Others if any	

24. Suggestions for promoting chickpea in the village?

a.---

b.---

c.---

Appendix 9. Randomization procedure for selection of mandals for primary survey.

Mandal	District	Chickpea area ('000 ha)	Cumulative total	Scale to Cum. total	Add random no. (0.8218)	Int. differences
Kanekal	Anantapur	9888	9888	0.75	1.57	1.00
Vidapanakal	Anantapur	15777	25665	1.95	2.77	1.00
Tadpatri	Anantapur	3218	28883	2.19	3.02	1.00
Uravakonda	Anantapur	11699	50320	3.82	4.64	1.00
Beluguppa	Anantapur	8114	58434	4.44	5.26	1.00
Gudur	Kurnool	4482	69199	5.26	6.08	1.00
Kurnool	Kurnool	7130	84399	6.41	7.23	1.00
Midthur	Kurnool	7016	94608	7.19	8.01	1.00
Adoni	Kurnool	3120	109750	8.34	9.16	1.00
Alur	Kurnool	11053	131770	10.01	10.83	1.00
Aspari	Kurnool	10900	142670	10.84	11.66	1.00
Banaganapalle	Kurnool	5654	148324	11.27	12.09	1.00
Chippagiri	Kurnool	16453	169650	12.89	13.71	1.00
Maddikera (East)	Kurnool	10167	179817	13.66	14.48	1.00
Koilkuntla	Kurnool	11955	194968	14.81	15.64	1.00
Dornipadu	Kurnool	5084	203679	15.48	16.30	1.00
Sanjamala	Kurnool	13282	216961	16.48	17.31	1.00
Uyyalawada	Kurnool	14240	237008	18.01	18.83	1.00
Mylavaram	Kadapa	4554	241561	18.35	19.18	1.00
Peddamudium	Kadapa	18261	259822	19.74	20.56	1.00
Rajupalem	Kadapa	8402	268224	20.38	21.20	1.00
Simhadripuram	Kadapa	5773	281961	21.42	22.24	1.00
Veerapunayunipalle	Kadapa	3232	294084	22.34	23.17	1.00
Parchur	Prakasam	6347	311397	23.66	24.48	1.00
Janakavarampanguluru	Prakasam	3400	319227	24.25	25.08	1.00
Naguluppalapadu	Prakasam	9151	332981	25.30	26.12	1.00
Ongole	Prakasam	3856	347551	26.41	27.23	1.00
Manopad	Mahabubnagar	7327	362665	27.55	28.38	1.00
Manoor	Medak	3646	372987	28.34	29.16	1.00
Madnoor	Nizamabad	6432	387493	29.44	30.26	1.00

Appendix 10. Socio-economic characteristics of non-chickpea sample farmers.

Appendix 10.1. Characteristics of non-chickpea sample households. (N=270).

Item	Unit	PRM (N=36)	KUR (N=117)	KAD (N=45)	ANA (N=45)	MED (N=9)	NIZ (N=9)	MAH (N=9)	Pooled (N=270)
Years of farming	Years	21.9	19.9	23.0	28.1	20.0	22.4	22.2	22.2
Household head (no.)	Male	36.0	117.0	45.0	45.0	9.0	9.0	9.0	270.0
Average age	Years	52.3	44.9	48.3	52.2	43.6	48.4	50.8	47.9
Education (years completed)	Years	5.0	5.0	7.0	6.0	4.0	3.0	5.0	5.0
Average size of family*	No.	3.9	5.2	5.1	5.1	5.0	5.8	4.2	5.0
No. of male*	No.	2.1	2.8	2.6	2.4	3.1	3.4	2.3	2.6
No. of female*	No.	1.8	2.4	2.5	2.7	1.9	2.4	1.9	2.4
No. of family labor (no.)*	Male	1.4	1.8	1.6	1.6	1.2	2.3	1.3	1.6
	Female	1.3	1.5	1.3	1.4	1.0	1.3	1.1	1.4
	Total	2.7	3.3	2.9	3.0	2.2	3.6	2.4	3.0
Participation in labor market (no.)*	Male	0.8	1.3	0.5	0.8	0.6	1.9	0.9	1.0
	Female	0.6	1.2	0.4	0.6	0.6	1.1	0.9	0.8
	Total	1.3	2.5	0.9	1.4	1.2	3.0	1.8	1.8

* including children in the family

The average years of farming experience of non-chickpea growers were 22 years. All the sample farmers were male headed households. The average age of the pooled sample was around 48 years. Most of non-chickpea growers having five years of completed education. The pooled average size of the family was 5.0. The family size was the highest in Nizamabad while the lowest was observed in Prakasam district. Three out of five members in the family are working as family labor. Around 60 percent of them even participate in the village labor market.

The average operational landholding of pooled non-chickpea farmers was 3.0 ha. The landholding across the districts are dominated by rainfed farming (Appendix 10.2). Nearly 15 percent of operational landholding are leased-in from land market. The average holdings were the highest in Anantapur followed by Kadapa, Kurnool, Nizamabad and Prakasam districts. The average relative landholding sizes of non-chickpea growers were smaller than the chickpea sample farmers in the respective study districts.

Appendix 10.2. Land holding particulars of non-chickpea sample households (ha/HH).									
Item	Type	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Pooled
Total own land holding	Irrigated	0.2	0.6	0.8	0.6	1.5	0.6	0.9	0.6
	Rain fed	1.2	1.7	2.2	3.3	0.6	2.0	1.3	1.9
	Total	1.4	2.3	3.0	3.9	2.1	2.6	2.1	2.5
Leased-in land	Irrigated	0.2	0.2	0.2	0.1	0.0	0.0	0.7	0.2
	Rain fed	1.1	0.3	0.1	0.1	0.0	0.0	0.1	0.3
	Total	1.3	0.6	0.2	0.2	0.0	0.0	0.8	0.5
Leased-out and permanent fallow	Irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rain fed	0.2	0.0	0.1	0.0	0.0	0.0	0.4	0.0
	Total	0.2	0.0	0.1	0.0	0.0	0.0	0.4	0.0
Operated landholding	Irrigated	0.4	0.9	1.0	0.7	1.5	0.6	1.6	0.8
	Rain fed	2.2	2.0	2.1	3.4	0.6	2.0	0.9	2.2
	Total	2.6	2.9	3.1	4.1	2.1	2.6	2.5	3.0

Appendix 10.3. Asset particulars of non-chickpea sample households ('000 $/HH).								
Item	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Pooled
Total land value	44.8	35.6	46.4	37.3	60.0	73.3	42.0	41.2
1.Irrigated	5.5	14.1	15.0	7.6	43.0	19.5	21.1	13.4
2. Dryland	39.2	21.5	31.5	29.7	16.9	53.8	20.9	27.8
3. Fallow land	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total livestock value	1.0	0.8	1.0	1.2	0.1	0.9	0.2	0.9
1. Draft Animals	0.1	0.2	0.1	0.3	0.0	0.3	0.0	0.2
2. She Buffaloes	0.9	0.4	0.7	0.5	0.1	0.2	0.2	0.5
3. Others	0.0	0.2	0.2	0.4	0.0	0.4	0.0	0.2
Total farm equipment	1.5	1.2	2.1	1.4	0.4	1.4	1.3	1.4
Total farm buildings	10.1	6.9	9.9	7.8	5.5	5.6	6.5	7.9
Total consumer durables	1.9	2.2	2.7	2.3	2.0	2.0	1.9	2.2
Total assets	59.3	46.7	62.2	49.9	67.9	83.2	51.9	53.6

USD $ = Rs.55

The average total asset value of non-chickpea sample farmers was 53,600 $ per household. Own land value contributes (77%) major share of the total asset value across study districts. It was followed by farm buildings, consumer durables and farm equipment. Nizamabad farmers possess the highest value of total assets followed by Medak, Kadapa, Prakasam and Mahabubnagar districts. The average asset value of non-chickpea farmers were relatively much lower (50%) than that of chickpea sample farmers in the study districts.

Appendix 10.4. Annual household incomes of non-chickpea households ('000 $/HH).								
Item	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Agriculture	0.67	1.65	1.08	1.31	2.11	1.69	2.39	1.35
Farm work	0.20	0.11	0.32	0.26	0.15	0.42	0.28	0.26
Non-farm work	0.23	0.09	0.36	0.27	0.38	0.49	0.22	0.28
Livestock	0.23	0.22	0.30	0.05	0.01	0.28	0.28	0.26
Caste occupations	0.00	0.00	0.02	0.00	0.10	0.00	0.00	0.01
Business	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.02
Migration	0.00	0.04	0.03	0.00	0.00	0.00	0.05	0.03
Remittances	0.04	0.24	0.06	0.12	0.06	0.00	0.02	0.08
Govt. Programs	0.11	0.14	0.20	0.14	0.10	0.14	0.12	0.15
Others	0.80	0.48	0.33	0.24	0.24	0.18	0.44	0.44
Total	2.27	2.97	2.73	2.40	3.16	3.20	3.86	2.86

The average annual household income of the pooled non-chickpea farmers was 2860 USD $ per household. Agriculture is contributing the major source (47%) of the total income across study districts. Participation in farm and non-farm work together contributing nearly 19 percent of total income for the pooled sample households. But, the net income generated from livestock contributed another 9 percent in total income. The share of contribution of agriculture in total household income was the highest in case of Prakasam followed by Medak and Nizamabad. The pooled average earnings per household of non-chickpea per annum was relatively lower (17%) when compared with chickpea farmers in the study.

The average total expenditure of pooled sample households of non-chickpea was 1120 USD $ per household per year (Appendix 10.5). Constrastingly, the share of non-food expenditure was much higher than the food expenditure per annum. The average expenditure levels were much higher in case of Kadapa followed by Medak, Anantapur, Kurnool and Nizamabad. Nevertheless, the average consumption standards of non-chickpea farmers were significantly lower (50%) than chickpea growers respectively across study districts.

Appendix 10.5. Household consumption of non-chickpea households ('000 $/HH/annum).

	PRM	KUR	KAD	ANA	MAH	MED	NIZ	Pooled
Food expenditure	0.09	0.18	0.24	0.28	0.12	0.23	0.17	0.19
Rice	0.02	0.07	0.11	0.13	0.04	0.09	0.05	0.08
Wheat	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
Chickpea	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01
Pigeonpea	0.00	0.01	0.03	0.03	0.01	0.02	0.01	0.02
Other pulses	0.01	0.01	0.02	0.02	0.00	0.02	0.01	0.01
Milk	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Other milk products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-vegetarian	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other food-expenditure	0.04	0.06	0.06	0.07	0.05	0.07	0.07	0.06
Non-food expenditure	0.68	0.91	1.19	0.93	0.89	1.16	0.65	0.93
Health	0.22	0.25	0.39	0.36	0.27	0.60	0.34	0.30
Education	0.20	0.39	0.59	0.31	0.33	0.33	0.08	0.37
Clothing	0.11	0.12	0.11	0.12	0.10	0.11	0.13	0.12
Entertainment	0.04	0.03	0.02	0.03	0.01	0.02	0.04	0.03
Ceremonies	0.04	0.03	0.01	0.03	0.01	0.02	0.01	0.03
Others	0.06	0.08	0.07	0.09	0.16	0.07	0.06	0.08
Grand Total	0.77	1.09	1.43	1.21	1.01	1.39	0.82	1.12

Appendix 11 Derivation of average time lag based on data on first year of adoption.

$$Adoption\ lag = A_{it} = \frac{\sum_{n}^{i=1}(t_{it} * n_{it})}{N_i}$$ Where,

t_a = year of first adoption

t_r = year of release of i^{th} variety

n_{it} = number of famers first adopted at t_{it} time period for i^{th} variety

N_i = total number of farmers first adopted by the i^{th} variety

Appendix 12. Variety and district-wise first adoption details.

Appendix 12.1. First adoption of chickpea improved cultivars in the sample (N=810).

Year	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	16	16	16	16	16	16	16	2	2	2	2	2	2	2
1991	21	21	21	21	21	21	21	5	5	5	5	5	5	5
1992	178	178	178	178	178	178	178	31	31	31	31	31	31	31
1993	288	288	288	288	288	288	288	32	32	32	32	32	32	32
1994	327	327	327	327	327	327	327	40	40	40	40	40	40	40
1995	349	349	349	349	349	349	349	43	43	43	43	43	43	43
1996	515	518	518	518	518	518	518	58	59	59	59	59	59	59
1997	796	809	809	809	809	809	809	99	102	102	102	102	102	102
1998	971	984	984	984	984	984	984	118	121	121	121	121	121	121
1999	1079	1092	1092	1092	1092	1092	1092	134	137	137	137	137	137	137
2000	1437	1470	1470	1470	1470	1470	1470	182	186	186	186	186	186	186
2001	1740	1787	1787	1787	1787	1787	1787	240	249	249	249	249	249	249
2002	2696	2818	2833	2843	2843	2843	2843	394	419	424	425	425	425	425
2003	2948	3200	3233	3253	3253	3253	3253	434	476	485	487	487	487	487
2004	3377	4010	4104	4188	4215	4215	4215	495	583	608	616	618	618	618
2005	3720	4899	5022	5117	5144	5144	5144	546	683	717	730	732	732	732
2006	3930	6172	6337	6439	6466	6466	6466	585	846	890	905	907	907	907
2007	3992	7911	8181	8298	8327	8349	8349	600	1043	1116	1135	1138	1140	1140
2008	4017	9758	10127	10472	10501	10523	10523	609	1240	1331	1370	1373	1375	1375
2009	4029	10447	10887	11389	11418	11448	11448	612	1328	1435	1491	1494	1498	1498
2010	4031	10649	11119	11758	11787	11825	11837	613	1367	1478	1544	1547	1552	1554
2011	4031	10728	11209	12023	12052	12090	12102	613	1378	1492	1582	1585	1590	1592
2012	4031	10730	11211	12060	12089	12141	12153	613	1379	1493	1589	1593	1600	1602

Appendix 12.2. First adoption of chickpea improved cultivars in Prakasam district (N=108).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1991	3	3	3	3	3	3	3	2	2	2	2	2	2	2
1992	17	17	17	17	17	17	17	7	7	7	7	7	7	7
1993	17	17	17	17	17	17	17	7	7	7	7	7	7	7
1994	17	17	17	17	17	17	17	7	7	7	7	7	7	7
1995	17	17	17	17	17	17	17	7	7	7	7	7	7	7
1996	20	20	20	20	20	20	20	9	9	9	9	9	9	9
1997	30	40	40	40	40	40	40	17	19	19	19	19	19	19
1998	32	42	42	42	42	42	42	19	21	21	21	21	21	21
1999	48	58	58	58	58	58	58	22	24	24	24	24	24	24
2000	56	66	66	66	66	66	66	24	26	26	26	26	26	26
2001	69	93	93	93	93	93	93	31	38	38	38	38	38	38
2002	89	150	166	166	166	166	166	40	61	66	66	66	66	66
2003	103	204	238	238	238	238	238	44	75	84	84	84	84	84
2004	106	247	310	320	320	320	320	45	88	110	111	111	111	111
2005	130	288	368	384	384	384	384	49	96	125	129	129	129	129
2006	135	346	445	465	465	465	465	50	115	151	156	156	156	156
2007	135	373	541	565	567	567	567	50	123	181	187	188	188	188
2008	135	434	679	704	706	706	706	50	132	203	210	211	211	211
2009	135	458	756	782	784	784	784	50	139	224	232	233	233	233
2010	135	458	759	785	787	787	787	50	139	225	233	234	234	234
2011	135	462	767	793	795	795	795	50	141	228	236	237	237	237
2012	135	462	767	793	795	795	795	50	141	228	236	237	237	237

Appendix 12.3. First adoption of chickpea improved cultivars in Kurnool district (N=351).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1990	15	15	15	15	15	15	15	1	1	1	1	1	1	1
1991	16	16	16	16	16	16	16	2	2	2	2	2	2	2
1992	91	91	91	91	91	91	91	13	13	13	13	13	13	13
1993	91	91	91	91	91	91	91	13	13	13	13	13	13	13
1994	103	103	103	103	103	103	103	17	17	17	17	17	17	17
1995	121	124	124	124	124	124	124	19	19	19	19	19	19	19
1996	243	246	246	246	246	246	246	29	30	30	30	30	30	30
1997	374	377	377	377	377	377	377	42	43	43	43	43	43	43
1998	442	445	445	445	445	445	445	48	49	49	49	49	49	49
1999	479	502	502	502	502	502	502	54	55	55	55	55	55	55
2000	632	655	655	655	655	655	655	76	78	78	78	78	78	78
2001	816	859	859	859	859	859	859	112	114	114	114	114	114	114
2002	1337	1455	1455	1465	1465	1465	1465	181	184	184	185	185	185	185
2003	1423	1857	1857	1867	1867	1867	1867	201	209	209	210	210	210	210
2004	1688	2485	2517	2560	2587	2587	2587	237	276	279	283	285	285	285
2005	1871	3376	3420	3468	3495	3495	3495	264	336	341	347	349	349	349
2006	1978	4285	4352	4400	4427	4427	4427	284	422	430	436	438	438	438
2007	1985	4874	4976	5029	5056	5056	5056	287	516	530	538	540	540	540
2008	1989	5096	5206	5469	5496	5496	5496	288	600	617	641	643	643	643
2009	1993	5125	5238	5588	5615	5615	5615	289	628	646	681	683	683	683
2010	1993	5151	5291	5704	5731	5731	5731	289	633	654	694	696	696	696
2011	1993	5151	5299	5795	5822	5822	5822	289	636	659	710	712	712	712
2012	1993	5151	5299	5828	5855	5855	5855	289	636	659	714	716	716	716

Appendix 12.4. First adoption of chickpea improved cultivars in Kadapa district (N=135).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	8	8	8	8	8	8	8	1	1	1	1	1	1	1
1997	80	80	80	80	80	80	80	8	8	8	8	8	8	8
1998	147	147	147	147	147	147	147	15	15	15	15	15	15	15
1999	182	182	182	182	182	182	182	19	19	19	19	19	19	19
2000	267	267	267	267	267	267	267	32	32	32	32	32	32	32
2001	287	287	287	287	287	287	287	36	36	36	36	36	36	36
2002	423	423	423	423	423	423	423	61	61	61	61	61	61	61
2003	438	438	438	448	448	448	448	62	62	62	63	63	63	63
2004	504	504	504	535	535	535	535	72	72	72	75	75	75	75
2005	542	623	623	654	654	654	654	80	88	88	91	91	91	91
2006	574	827	827	858	858	858	858	85	112	112	115	115	115	115
2007	583	1239	1241	1277	1277	1279	1279	88	149	150	154	154	155	155
2008	593	1597	1613	1668	1668	1670	1670	92	185	188	195	195	196	196
2009	598	1802	1833	1957	1957	1967	1967	93	208	212	224	224	226	226
2010	598	1903	1934	2133	2133	2143	2143	93	224	228	245	245	247	247
2011	598	1934	1965	2255	2255	2277	2277	93	228	232	262	262	265	265
2012	598	1934	1965	2257	2257	2279	2279	93	228	232	263	263	266	266

Appendix 12.5. First adoption of chickpea improved cultivars in Anantapur district (N=135).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	8	8	8	8	8	8	8	1	1	1	1	1	1	1
1993	118	118	118	118	118	118	118	2	2	2	2	2	2	2
1994	143	143	143	143	143	143	143	5	5	5	5	5	5	5
1995	148	148	148	148	148	148	148	6	6	6	6	6	6	6
1996	181	181	181	181	181	181	181	8	8	8	8	8	8	8
1997	221	221	221	221	221	221	221	14	14	14	14	14	14	14
1998	255	255	255	255	255	255	255	17	17	17	17	17	17	17
1999	275	275	275	275	275	275	275	20	20	20	20	20	20	20
2000	384	384	384	384	384	384	384	30	30	30	30	30	30	30
2001	465	465	465	465	465	465	465	40	40	40	40	40	40	40
2002	667	685	685	685	685	685	685	65	66	66	66	66	66	66
2003	784	817	817	817	817	817	817	78	81	81	81	81	81	81
2004	862	910	910	910	910	910	910	86	91	91	91	91	91	91
2005	946	1076	1076	1076	1076	1076	1076	94	102	102	102	102	102	102
2006	997	1244	1244	1244	1244	1244	1244	101	126	126	126	126	126	126
2007	1029	1679	1679	1679	1679	1699	1699	105	172	172	172	172	173	173
2008	1029	2439	2439	2439	2439	2467	2467	105	219	219	219	219	222	222
2009	1029	2589	2589	2589	2589	2617	2617	105	232	232	232	232	235	235
2010	1029	2619	2619	2619	2619	2647	2659	105	236	236	236	236	239	241
2011	1029	2634	2634	2634	2634	2662	2674	105	237	237	237	237	240	242
2012	1029	2636	2636	2637	2637	2667	2679	105	238	238	239	239	243	245

Appendix 12.6. First adoption of chickpea improved cultivars in Medak district (N=27)

Year	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	2	2	2	2	2	2	2	1	1	1	1	1	1	1
1992	63	63	63	63	63	63	63	10	10	10	10	10	10	10
1993	63	63	63	63	63	63	63	10	10	10	10	10	10	10
1994	65	65	65	65	65	65	65	11	11	11	11	11	11	11
1995	65	65	65	65	65	65	65	11	11	11	11	11	11	11
1996	65	65	65	65	65	65	65	11	11	11	11	11	11	11
1997	81	81	81	81	81	81	81	16	16	16	16	16	16	16
1998	85	85	85	85	85	85	85	17	17	17	17	17	17	17
1999	85	85	85	85	85	85	85	17	17	17	17	17	17	17
2000	85	85	85	85	85	85	85	17	17	17	17	17	17	17
2001	90	90	90	90	90	90	90	18	18	18	18	18	18	18
2002	110	110	110	110	110	110	110	25	25	25	25	25	25	25
2003	110	110	110	110	110	110	110	25	25	25	25	25	25	25
2004	110	110	110	110	110	110	110	25	25	25	25	25	25	25
2005	110	110	110	110	110	110	110	25	25	25	25	25	25	25
2006	113	113	113	113	113	113	113	26	26	26	26	26	26	26
2007	113	113	113	113	113	113	113	26	26	26	26	26	26	26
2008	113	119	119	119	119	119	119	26	28	28	28	28	28	28
2009	113	151	151	151	151	151	151	26	30	30	30	30	30	30
2010	115	182	182	182	182	182	182	27	39	39	39	39	39	39
2011	115	185	185	185	185	185	185	27	40	40	40	40	40	40
2012	115	185	185	185	186	186	186	27	40	40	40	41	41	41

Appendix 12.7. First adoption of chickpea improved cultivars in Mahabubnagar district (N=27).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	12	12	12	12	12	12	12	2	2	2	2	2	2	2
1998	12	12	12	12	12	12	12	2	2	2	2	2	2	2
1999	12	12	12	12	12	12	12	2	2	2	2	2	2	2
2000	16	16	16	16	16	16	16	3	3	3	3	3	3	3
2001	16	16	16	16	16	16	16	3	3	3	3	3	3	3
2002	37	37	37	37	37	37	37	10	10	10	10	10	10	10
2003	57	57	57	57	57	57	57	12	12	12	12	12	12	12
2004	74	83	83	83	83	83	83	17	18	18	18	18	18	18
2005	83	96	96	96	96	96	96	19	21	21	21	21	21	21
2006	87	105	105	109	109	109	109	20	24	24	25	25	25	25
2007	92	152	152	156	156	156	156	22	32	32	33	33	33	33
2008	92	211	211	215	215	215	215	22	45	45	46	46	46	46
2009	92	222	222	226	226	226	226	22	48	48	49	49	49	49
2010	92	222	222	226	226	226	226	22	48	48	49	49	49	49
2011	92	222	222	226	226	226	226	22	48	48	49	49	49	49
2012	92	222	222	226	226	226	226	22	48	48	49	49	49	49

Appendix 12.8. First adoption of chickpea improved cultivars in Nizamabad district (N=27).

	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
Year	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	37	37	37	37	37	37	37	12	12	12	12	12	12	12
2003	37	37	37	37	37	37	37	12	12	12	12	12	12	12
2004	38	38	38	38	38	38	38	13	13	13	13	13	13	13
2005	43	43	43	43	43	43	43	15	15	15	15	15	15	15
2006	51	59	59	59	59	59	59	19	21	21	21	21	21	21
2007	60	70	70	70	70	70	70	22	25	25	25	25	25	25
2008	72	87	87	87	87	87	87	26	31	31	31	31	31	31
2009	75	133	133	133	133	133	133	27	43	43	43	43	43	43
2010	75	150	150	150	150	150	150	27	48	48	48	48	48	48
2011	75	150	150	150	150	150	150	27	48	48	48	48	48	48
2012	75	150	150	150	150	150	150	27	48	48	48	48	48	48

Appendix 13. Yield variability in chickpea cultivation

This appendix section uses survey results to estimate the yield distributions for three possible scenarios: normal year, bad and best seasons. It presents the extent of yield variability in chickpea based on statistical measures of mean and standard deviation during normal years and deviations from normal years, ie, bad and best seasons. This is used in examining the alternative yield scenarios which differs across the seven major chickpea growing districts representing different agro-ecologies where chickpea is grown. Key observations from the yield analysis are associated with variations in rainfall regimes, soil type and length of growing period.

The influence of drought was much conspicuous on chickpea in parts of Andhra Pradesh (especially in Kurnool, Anantapur and Mahabubnagar districts) during the survey year ie, 2011-12. Subsequently, the drought impact was also observed in certain parts of Kurnool, Anantapur and Mahabubnagar districts during cropping year 2012-13. During the household data collection and village Focus Group Meetings (FGMs), the sample farmers were asked to provide their perceptions about the normal, bad and best yields obtained in chickpea cultivation so far in the respective households and villages. Based on their perceptions in chickpea cultivation during almost 5-10 years, the histograms were fitted using 'Normal' distribution.

Figures 13.1 and 13.2. respectively present the histograms for JG 11 and KAK 2 (the popular cultivars occupy nearly 90 percent of the area) in Prakasam district. The average normal yield for JG 11 in the district was around 856 kg per acre. The bad yield based on perceptions was nearly 630 kg per acre while the best yields obtained by sample farmers were 1062 kg per acre. On average, nearly 30-40 percent yield deviations per acre were observed to be due to climatic aberrations. The mean survey year yield per acre was 871 which were close to normal yield of that district. Similarly in the case of KAK 2, the normal yield was 777 kg per acre, whereas the bad and best yields were 570 and 959 kg per acre respectively. Approximately 20-30 percent yield deviations were found in the analysis. The average yield during the survey period observed was 836 kg per acre which is slightly higher than the normal yield. It confirms that Prakasam did not experience any drought during 2011-12 survey/cropping year.

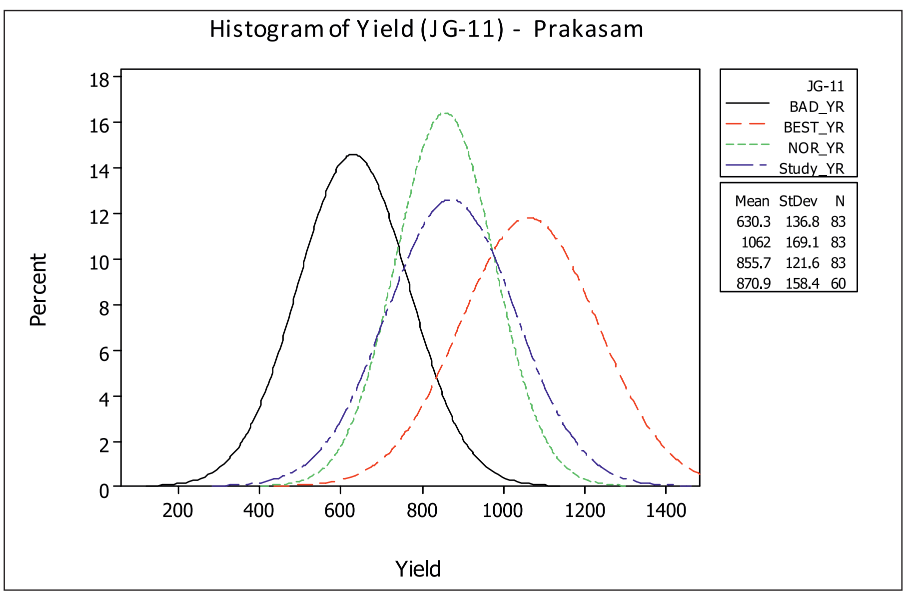

Figure 13.1. Yield distribution of JG 11 in Prakasam district.

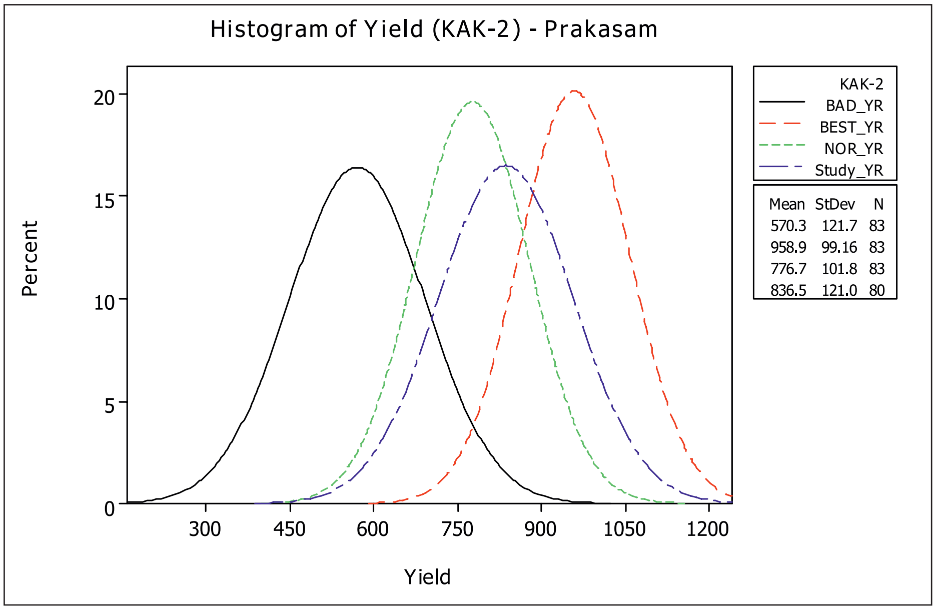

Figure 13.2. Yield distribution of KAK 2 in Prakasam district.

Figures 13.3 and 13.4. depict the histograms of JG 11 and Vihar (most popular in the district) cultivar yield distributions respectively in Kurnool district. The normal yield for JG 11 cultivar was around 650 kg per acre. The bad and best yields per acre ranged from 256 to 861 kg per acre. A huge variation in yield perceptions was observed because Kurnool is sensitive to rainfall deviations. The actual average yield obtained during the survey year was 322 kg/acre. It was almost half of the normal yield in the district. Similarly in the case of Vihar, the normal yield is at 646 kg per acre while the actual mean yield reported in the household survey was only 577 kg per acre. A marginal decrease (10 percent) in yield was observed in the analysis. The performance of Vihar was slightly better than JG 11 under drought conditions. This clearly lends support to the statement that Kurnool district is far more sensitive to terminal drought than Prakasam district.

Figures 13.5. and 13.6. report the 'normal' distribution of chickpea yields respectively for JG 11 and Vihar cultivars in Kadapa district. JG 11 is the pre-dominant cultivar (85-90%) in the district while few farmers started growing kabuli type Vihar. The mean normal yield of the district is around 587 kg per acre based on farmers' perception. Nearly 25-40 percent deviations were observed between best and bad yields relative to normal yields. However, the actual yield reported by chickpea households was 597 kg/acre. This is pretty close to the normal yield and indicates that the influence of climate on the district is limited. In the case of Vihar, the perceived normal yield was 629 kg per acre. During the survey year, Vihar performed better (749 kg/acre) than normal. The analysis provides clearly that Kadapa did not experience drought during the cropping year 2011-12.

The details of the performance of chickpea in Anantapur district is illustrated in Figure 13.7. JG 11 is the most dominant desi cultivar (around 95%) in the district. The normal yield of JG 11 was reported to be 487 kg per acre which is far lower than Prakasam, Kurnool and Kadapa districts. Anantapur is one of most drought-prone districts of Andhra Pradesh, with average rainfall of around 500 mm. As expected, huge deviations in bad and best yields were observed relative to normal yield. The actual

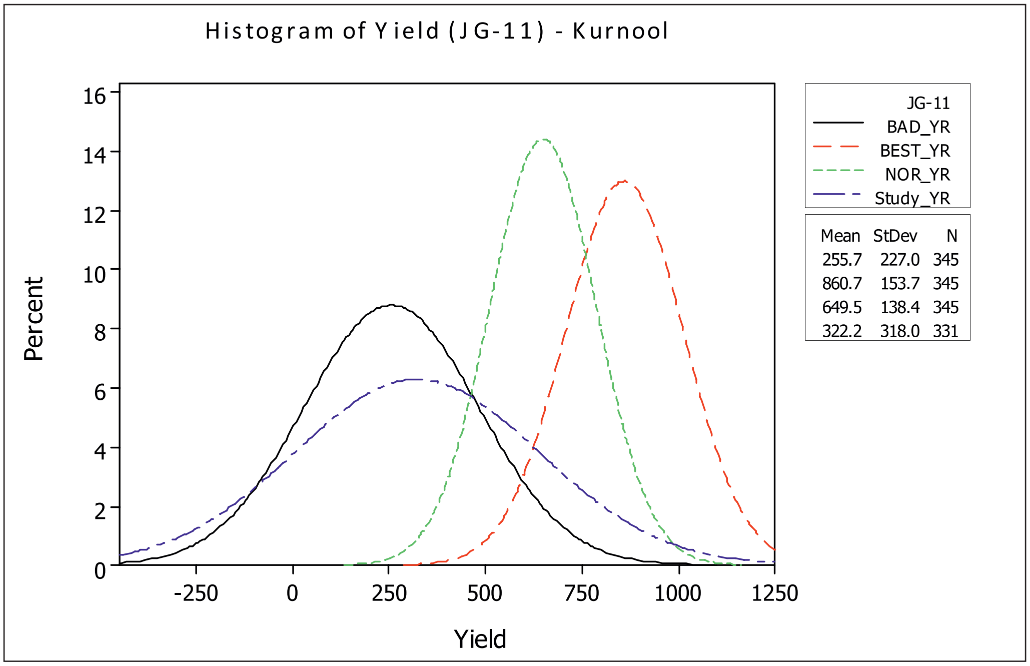

Figure 13.3. Yield distribution of JG 11 in Kurnool district .

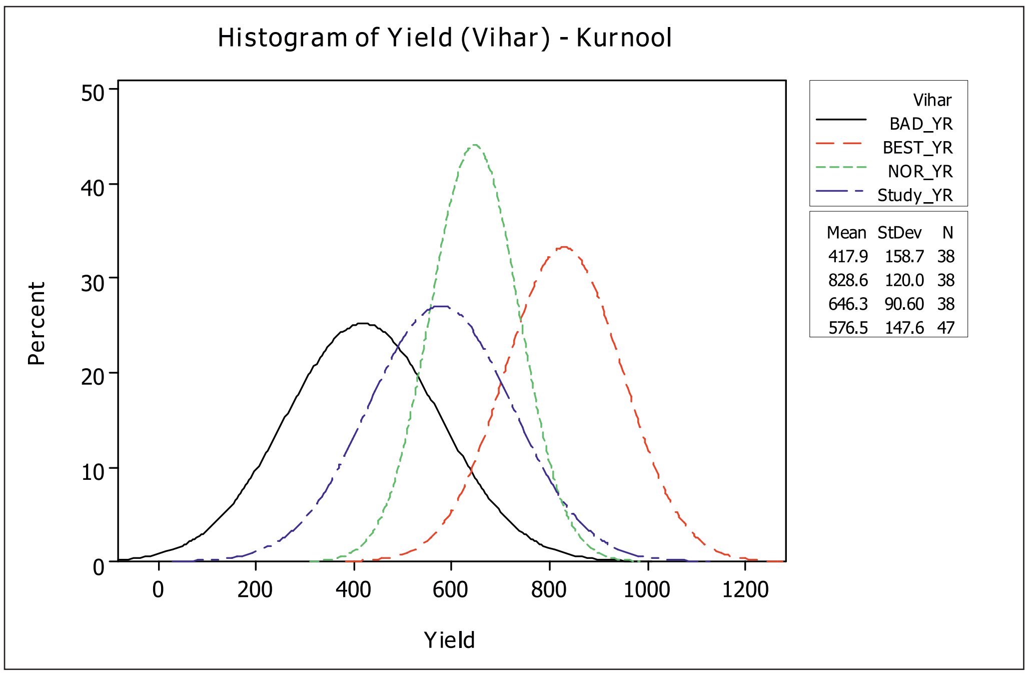

Figure 13.4. Yield distribution of Vihar in Kurnool district .

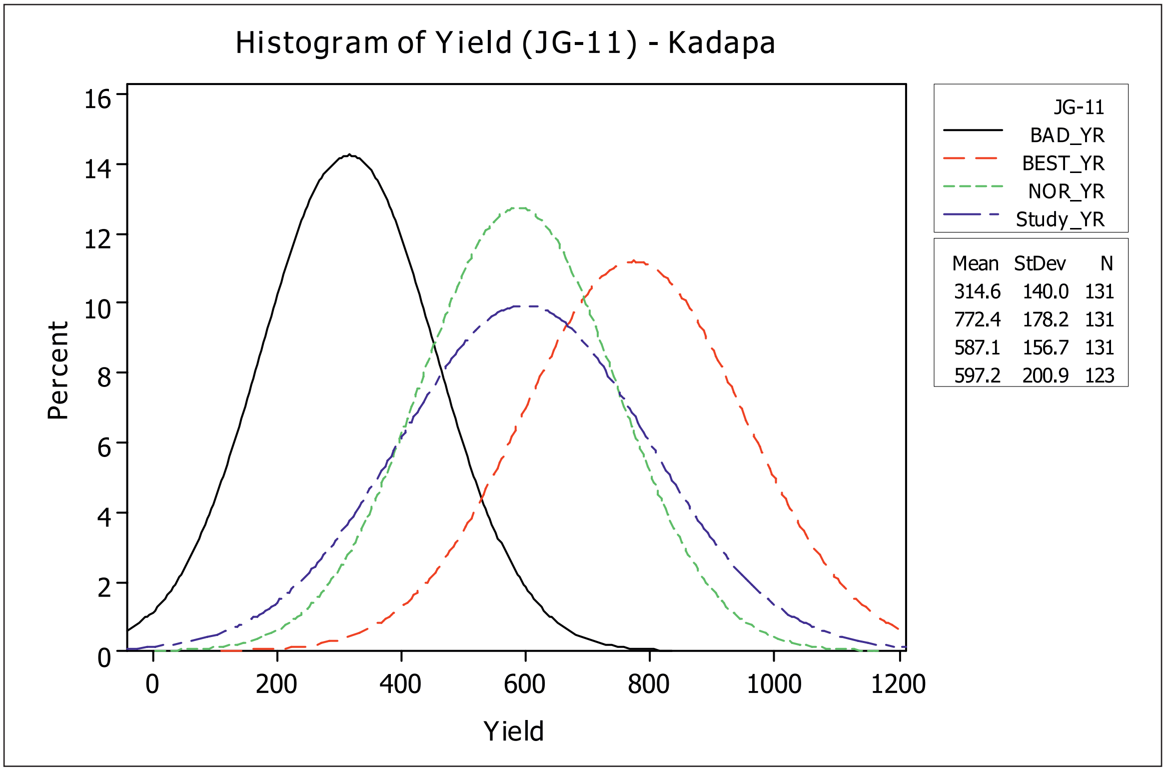

Figure 13.5. Yield distribution of JG 11 in Kadapa district .

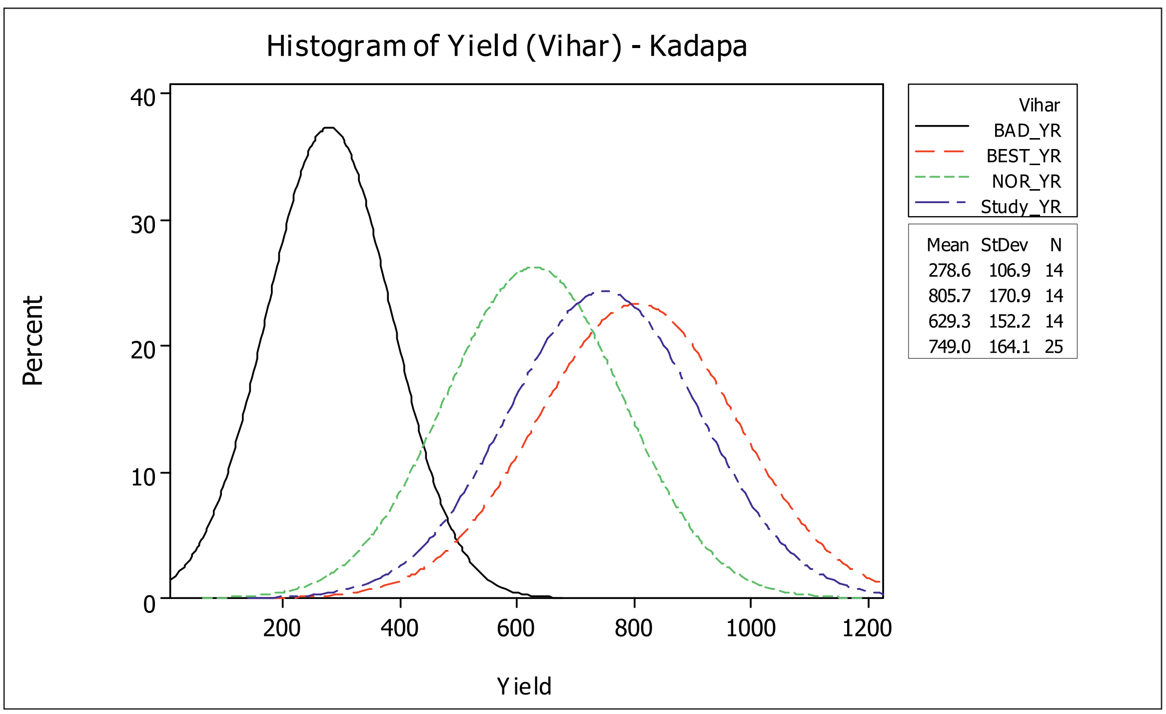

Figure 13.6. Yield distribution of Vihar in Kadapa district.

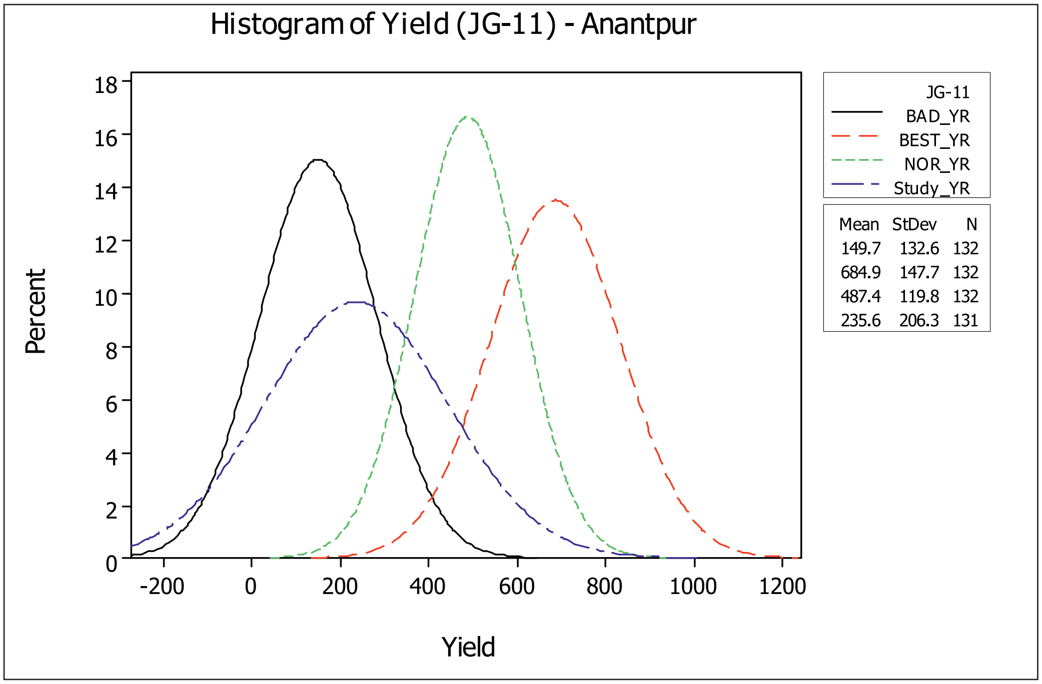

Figure13.7. Yield distribution of JG 11 in Anantapur district.

mean yield during survey year was at 236 kg per acre which is almost half the normal yield. Over all, the entire exercise confirms that Anantapur experienced severe drought during 2011-12.

Another drought-prone district in the state of Andhra Pradesh was Mahabubnagar. Even though the average normal rainfall in the district is a little higher, it experiences maximum deviations in its distributions. Due to the negative deviations during the terminal crop period, the extent of yield reductions tend to be higher. Figure 13.8. elucidates the extent of variations in yield perceptions across different climatic situations in Mahabubnagar. The normal yield informed by sample farmers was 635 kg/acre. The yield data collected through primary survey exactly matched with the bad yield situation in the histogram. This clearly shows that Mahabubnagar district was severely affected by drought during 2011-12.

Figures 13.9. and 13.10. elucidate the performance of chickpea in Medak and Nizamabad districts of Andhra Pradesh. JG 11 is the dominant desi cultivar in these districts. However, the old Annigeri cultivar was observed in traces in these districts. Chickpea is mostly grown as a sole crop except in Medak. Farmers prefer to grow chickpea as an inter-crop with safflower (9:1 ratio) here. Nizamabad is a new niche area for spreading of chickpea in the state.

Medak is a traditional albeit low key chickpea grower since 1990s. The average normal yield revolves around 647 kg per acre. The mean actual survey data reported 677 kg per acre. This clearly shows that Medak was not affected by drought.

Similarly, farmers' in Nizamabad perceived the average normal yield of 755 kg per acre. The best yields reported by farmers were higher in Nizamabad than Kurnool, Anantapur, Kadapa, Mahabubnagar and Medak. This indicates the huge potential of the crop in the district coupled with

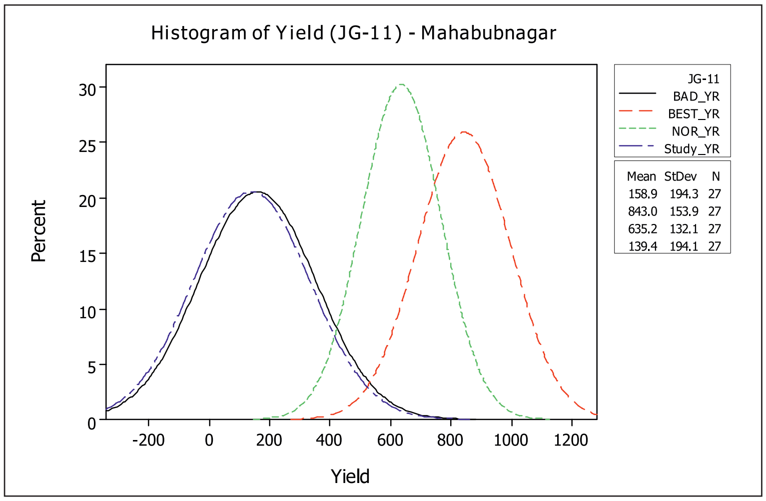

Figure 13.8. Yield distribution of JG 11 in Mahabubnagar district.

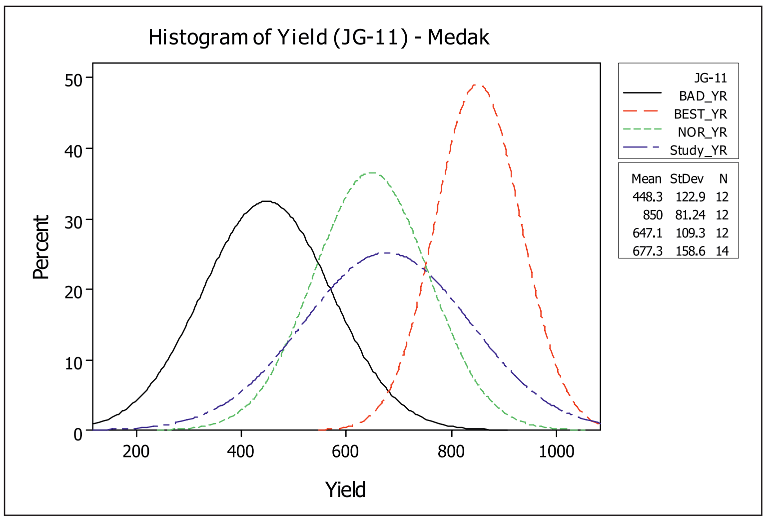

Figure 13.9. Yield distribution of JG 11 in Medak district .

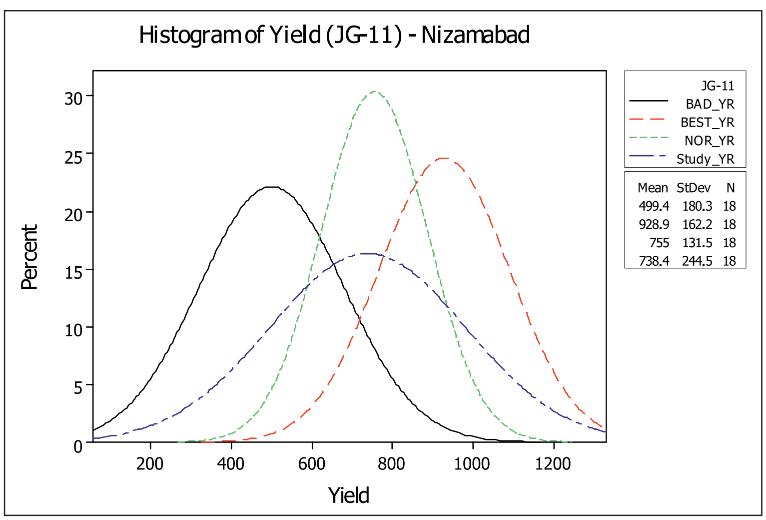

Figure 13.10. Yield distribution of JG 11 in Nizamabad district.

availability of better soils and rainfall patterns. The actual mean yields stated by sample farmers were 738 kg per acre. This is much closer to normal yields in the district and indicates no terminal drought or yield losses.

Appendix 14. Cultivar-wise costs and returns in chickpea cultivation.

Appendix 14.1. Costs and returns of JG 11 ($ per ha) cultivation across study districts

Item	PRM 23 plots	KUR 183 plots	ANA 70 plots	KAD 65 plots	MED 2 plots	MAH 10 plots	NIZ 10 plots
Land preparation	105.8	55.9	55.5	68.4	64.4	76.8	88.0
Seed bed preparation	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Compost/animal penning	18.0	45.2	37.3	21.1	0.0	0.0	0.0
Planting	42.2	20.3	23.0	21.2	32.6	30.5	29.6
Seed cost	116.8	98.2	104.7	107.5	63.6	115.1	79.1
Seed treatment	0.2	2.0	2.5	2.6	0.0	5.0	0.0
Fertilizer cost	83.8	85.1	52.5	87.3	57.3	92.3	59.8
Micro-nutrient	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interculture	0.0	10.8	15.6	15.2	0.0	14.0	6.4
Weeding	49.4	28.1	22.6	32.2	39.3	40.2	50.9
Plant protection	64.6	42.8	37.7	58.6	31.8	46.9	78.6
Irrigation	0.0	1.3	0.9	0.0	0.0	0.0	3.1
Watching	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harvesting	79.3	34.7	30.2	49.7	51.6	18.9	62.2
Threshing	86.9	30.4	24.7	43.2	57.8	10.7	55.1
Marketing	12.4	6.5	5.4	8.2	11.8	2.2	16.3
Total variable cost (TVC)	659.4	461.4	412.5	515.2	410.2	452.8	529.2
Fixed cost/acre	546.7	336.7	226.5	280.5	404.2	332.3	390.7
Total cost (TC)	1206.2	798.1	639.0	795.7	814.3	785.1	919.9
Grain yield (kg/ha actual)	2339.1	842.3	610.1	1380.7	1746.3	165.5	1645.0
Gross returns	1713.5	634.3	430.6	1026.4	988.6	102.4	911.5
COP/ton over VC	281.9	547.8	676.2	373.2	234.9	2736.2	321.7
COP/ton over TC	515.7	947.5	1047.4	576.3	466.3	4744.4	559.2
Grain yield (kg/ha normal)	2114.3	1605.5	1202.9	1449.9	1598.1	1568.5	1864.9
COP/ton over VC – N	311.9	287.4	342.9	355.4	256.7	288.7	283.8
COP/ton over TC – N	570.5	497.1	531.2	548.8	509.6	500.6	493.3

N = Normal yield; COP = Cost of Production

The details of costs and returns in JG 11 cultivation per ha across study districts are presented in the Appendix 14.1. The average gross returns per ha were highly significant in Prakasam district followed by Kadapa, Medak and Nizamabad. However, the total costs per ha were the lowest in case of Anantapur followed by Mahabubnagar, Kadapa and Kurnool districts. The net returns were marginally higher in Prakasam followed by Kadapa and Medak districts. The values were significantly negative in Mahabubnagar district due to drought. Similarly, Anantapur and Kurnool districts also could not recover the full costs invested in chickpea cultivation. In the case of Nizamabad, the total costs were just covered with gross returns per ha. However, the costs of production per ton under actual yields were lower in Medak followed by Prakasam districts. The average cost of production per ton across seven districts with normal yields was $521.6.

Appendix 14.2. Costs and returns of KAK 2 ($ per ha) cultivation across study districts.

Item	PRM 36 plots
Land preparation	107.1
Seed bed preparation	0.0
Compost/animal penning	10.0
Planting	40.5
Seed cost	173.3
Seed treatment	0.4
Fertilizer cost	109.1
Micro-nutrient	2.1
Interculture	0.0
Weeding	46.0
Plant protection	67.1
Irrigation	0.0
Watching	0.0
Harvesting	86.9
Threshing	91.1
Marketing	13.8
Total variable cost (VC)	747.4
Fixed cost/acre	559.5
Total cost (TC)	1306.9
Grain yield (kg/ha actual)	2037.8
Price ($/ton)	854.5
Gross returns	1733.5
COP/ton over VC	366.8
COP/ton over TC	641.3
Grain yield (kg/ha normal)	1919.2
COP/ton over VC – N	389.4
COP/ton over TC – N	680.9

N = Normal yield; COP = Cost of Production

The average costs and returns of KAK 2 cultivar in Prakasam district is summarized in Appendix 14.2. The gross returns earned per ha of KAK 2 were $1733.5. While the total costs associated with its production was $1307. An average net profit of $426.6 per ha was enjoyed by the chickpea farmer. The costs of production per ton were slightly higher in case of KAK 2 when compared with JG 11. The seed costs of kabuli cultivars per ha are significantly higher than desi types.

Appendix 14.3. Costs and returns of Vihar ($ per ha) cultivation across study districts.

Item	KUR 17 plots	KAD 11 plots
Land preparation	62.3	76.3
Seed bed preparation	0.0	0.0
Compost/animal penning	41.9	12.6
Planting	22.5	21.4
Seed cost	127.9	143.3
Seed treatment	3.3	2.6
Fertilizer cost	104.2	94.3
Micro-nutrient	0.0	0.0
Interculture	20.5	13.5
Weeding	39.4	35.4
Plant protection	46.4	54.3
Irrigation	3.8	0.0
Watching	0.0	0.0
Harvesting	57.2	48.6
Threshing	48.2	48.7
Marketing	12.0	8.5
Total variable cost (VC)	589.7	559.4
Fixed cost/acre	462.3	306.2
Total cost (TC)	1052.0	865.6
Grain yield (kg/ha actual)	1390.6	1968.6
Price ($/ton)	800.0	854.5
Gross returns	1118.1	1667.9
COP/ton over VC	424.0	284.2
COP/ton over TC	756.5	439.7
Grain yield (kg/ha normal)	1590.7	1553.6
COP/ton over VC – N	370.7	360.1
COP/ton over TC – N	661.3	557.1

N = Normal yield; COP = Cost of Production

The detailed break-up of costs and returns of 'Vihar' cultivar are presented in appendix 10.3. The average gross returns per ha were higher in the case of Kadapa than Kurnool. The total costs incurred per ha was higher for Kurnool district. The mean net returns per ha were significantly larger for Kadapa. These differences may be due to the differential productivity in the study districts. The costs of production per ton were slightly lower than KAK 2 but higher than JG 11.

Appendix 15. Costs and returns from chickpea by category of farmers

With the observed adoption patterns of different groups of farmers in Andhra Pradesh, the estimation of cost and returns was undertaken for each category of farmers in the sample:

Non-adopters, NA – farmers who continue to grow the old varieties

Adopters, A1 - replacing existing varieties with the new short-duration varieties

Adopters, A2 - substituting the new varieties for other crops grow on part of the farm

Adopters, A3 - acquiring additional land to grow the new varieties

Switchers, SW - farmers who have not grown chickpeas before and replace other crops

Appendix 15.1 summarizes the categorization of sample farmers based on the extent of improved chickpea cultivars in their farms across study districts. The detailed break-up shows that the number of non-adopters in the total sample was only 28 (3.45%) out of 810. Among the four categories of adopters, the highest number of sample farmers fell under A1 (30.8%) followed by switchers (24.3%), A3 (21.8%) and A2 (19.4%). Overall, the plot-wise costs and returns data at household level were collected from only 1/3rd of the total sample ie, 270 HH covered out of 810 HH. By using randomization procedure, crop economics data were only collected from 3 out of 9 HH from each selected village. Due to the smaller size of the non-adopters (28), the probability of non-adopter household being selected under costs and returns data collection was very low (33.3%). Around 10 HH plot-level costs and returns data were collected across three study districts. In Medak, chickpea was cultivated along with safflower at 9:1 proportion. Such inter-crop based plot-level costs information was not used for costs and returns analysis. With these limitations, the non-adopters' costs and returns analysis was not compared with adopters' information. However, the computation of cost and returns by other category of farmers is presented in following tables.

Appendix 15.1. Categorization of sample households (N=810).

		Sample size for each category of farmers by district/mandal					
District	Mandal	NA	A1	A2	A3	SW	Total
Anantapur			46	43	16	30	135
	Beluguppa		13	11	3	0	27
	Kanekal		4	17	4	2	27
	Tadiparthi		3	4	2	18	27
	Uravakonda		11	7	5	4	27
	Vidapanakal		15	4	2	6	27

Appendix 15.1. Categorization of sample households (N=810).

District	Mandal	Sample size for each category of farmers by district/mandal					Total
		NA	A1	A2	A3	SW	
Kadapa			36	33	24	42	135
	Mylavaram		11	8	6	2	27
	Peddamudium		11	9	6	1	27
	Rajupalem		5	8	9	5	27
	Simhadripuram		4	4	3	16	27
	Veerapunayunipalle		5	4	0	18	27
Kurnool		2	128	64	95	62	351
	Adoni		14	2	3	8	27
	Alur		6	6	8	7	27
	Aspari		10	6	5	6	27
	Banaganapalle		16	2	4	5	27
	Chippargiri		5	5	10	7	27
	Dorinipadu		12	8	4	3	27
	Gudur	2	6	4	9	6	27
	Koilkuntla		7	4	12	4	27
	Kurnool		8	2	14	3	27
	Maddikera (East)		10	8	7	2	27
	Midthur		12	6	6	3	27
	Sanjamala		12	4	9	2	27
	Uyyalawada		10	7	4	6	27
Mahabubnagar			7	8	8	4	27
	Manopad		7	8	8	4	27
Medak		14	13				27
	Manoor	14	13				27
Nizamabad		12	11		3	1	27
	Madnoor	12	11		3	1	27
Prakasam			9	10	31	58	108
	Janakavarampanguluru		1	2	10	14	27
	Naguluppalapadu		2	3	5	17	27
	Ongole		4	2	10	11	27
	Parchuru		2	3	6	16	27
Grand total		28	250	157	177	197	810

Appendix 15.2. COC across category of JG 11 farmers ($ per ha).				
Item	A1 92 plots	A2 99 plots	A3 96 plots	SW 76 plots
Land preparation	61.3	58.0	57.5	67.0
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	33.1	39.5	27.4	19.4
Planting	22.5	21.5	20.4	28.0
Seed cost	98.5	101.0	103.7	105.6
Seed treatment	2.2	2.2	2.1	2.1
Fertilizer cost	80.5	65.9	76.8	84.6
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	11.5	12.1	11.2	11.9
Weeding	29.9	28.2	28.0	33.6
Plant protection	48.4	46.7	46.8	46.1
Irrigation	2.2	1.3	0.2	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	38.9	35.7	37.5	46.7
Threshing	35.2	29.5	33.2	45.2
Marketing	7.5	6.1	6.8	8.0
Total variable cost (TVC)	471.6	447.8	451.7	498.3
Fixed cost/acre (FC)	319.0	282.8	345.3	339.8
Total cost (TC)	790.6	730.6	797.0	838.0
Grain yield (kg/ha actual)	1079.4	839.8	946.0	1165.8
Price ($/ton)	654.5	618.2	690.9	672.7
Gross returns	757.0	631.5	738.4	808.1
COP/ton over VC	436.9	533.2	477.5	427.4
COP/ton over TC	732.4	870.0	842.4	718.8
Grain yield (kg/ha normal)	1620.3	1632.7	1667.3	1568.5
COP/ton over VC - N	291.1	274.3	270.9	317.7
COP/ton over TC – N	487.9	447.5	478.0	534.3

N = Normal yield; COP = Cost of Production

Appendix 15.3. COC across category of KAK 2 farmers ($ per ha).				
Item	A1 2 plots	A2 2 plots	A3 15 plots	SW 20 plots
Land preparation	102.2	110.2	97.1	99.3
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	0.0	0.0	5.5	13.8
Planting	41.5	43.2	30.1	43.5
Seed cost	148.2	181.9	174.2	171.9
Seed treatment	0.0	0.0	1.1	0.3
Fertilizer cost	93.2	89.7	119.5	100.7
Micro-nutrient	0.0	0.0	0.0	3.8
Interculture	0.0	0.0	1.6	0.0
Weeding	46.9	44.0	37.8	48.8
Plant protection	50.3	46.7	67.6	68.3
Irrigation	0.0	0.0	0.0	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	94.3	94.8	78.0	85.5
Threshing	105.8	87.9	81.6	88.3
Marketing	18.0	20.8	11.7	13.7
Total variable cost (TVC)	700.4	719.1	705.9	737.8
Fixed cost/acre (FC)	538.9	494.0	509.0	576.0
Total cost (TC)	1239.3	1213.1	1214.9	1313.8
Grain yield (kg/ha actual)	2178.5	1901.9	2015.5	2040.2
Price ($/ton)	890.9	854.5	854.5	854.5
Gross returns	1983.4	1622.1	1723.4	1723.4
COP/ton over VC	321.5	378.1	350.2	361.6
COP/ton over TC	568.9	637.8	602.8	643.9
Grain yield (kg/ha normal)	2003.2	1993.3	1906.8	1897.0
COP/ton over VC – N	349.6	360.7	370.2	388.9
COP/ton over TC – N	618.7	608.6	637.1	692.6

N = Normal yield; COP = Cost of Production

Appendix 15.4. COC across category of Vihar farmers ($ per ha).

Item	A1 5 plots	A2 7 plots	A3 9 plots	SW 7 plots
Land preparation	64.0	80.8	62.2	64.7
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	54.7	44.3	16.0	17.8
Planting	25.3	21.2	23.2	22.6
Seed cost	119.2	151.1	135.9	124.8
Seed treatment	1.3	2.0	4.3	3.6
Fertilizer cost	115.1	85.1	103.2	95.2
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	22.4	13.9	17.2	18.9
Weeding	34.2	42.9	30.2	36.2
Plant protection	55.7	42.4	54.8	45.3
Irrigation	0.0	2.6	5.2	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	61.0	50.7	48.9	58.2
Threshing	43.1	49.7	46.3	48.5
Marketing	15.1	9.2	10.7	6.1
Total variable cost (TVC)	611.2	595.9	558.0	541.9
Fixed cost/acre (FC)	368.3	295.1	424.1	500.4
Total cost (TC)	979.4	891.0	982.2	1042.3
Grain yield (kg/ha actual)	1264.6	1817.9	1785.8	1452.4
Price ($/ton)	690.9	872.7	800.0	872.7
Gross returns	865.1	1610.4	1434.3	1263.8
COP/ton over VC	483.3	327.8	312.5	373.1
COP/ton over TC	774.5	490.1	550.0	717.7
Grain yield (kg/ha normal)	1524.0	1647.5	1449.9	1642.6
COP/ton over VC - N	401.0	361.7	384.9	329.9
COP/ton over TC – N	642.7	540.9	677.4	634.6

N = Normal yield; COP = Cost of Production

Appendix 16. Competitiveness of chickpea with other crops in sample districts.

Understanding the substitutability/competitiveness of chickpea across study districts is important for better assessment of chickpea adoption in Andhra Pradesh. This exercise shows the distinct advantage of chickpea in comparison with other competing crops during the postrainy season. Appendix 16.1 to 16.7 discuss the competitiveness of chickpea with other crops in the seven study districts in the state.

Appendix 16.1. Competitiveness of chickpea in Prakasam district ($ per ha).

Item	Chickpea (60 plots*)	Maize (3 plots)	Tobacco (8 plots)
Land preparation	107.3	88.8	113.4
Seed bed preparation	0.0	5.3	21.1
Compost/animal penning	12.9	0.0	60.4
Planting	41.1	39.3	76.6
Seed cost	152.1	113.8	131.8
Seed treatment	0.3	4.2	0.0
Fertilizer cost	99.4	119.5	141.9
Micro-nutrient	1.3	0.0	0.0
Interculture	0.0	14.7	62.1
Weeding	47.2	56.2	64.5
Plant protection	65.8	35.0	136.1
Irrigation	0.0	50.7	18.8
Watching	0.0	0.0	0.0
Harvesting	84.0	66.9	222.7
Threshing	89.5	103.6	781.6
Marketing	13.1	17.7	13.4
Total variable cost (TVC)	714.0	715.6	1844.3
Fixed cost	555.8	538.9	522.1
Total cost (TC)	1269.7	1254.5	2366.4
Grain yield (kg/ha actual)	2148.9	4117.5	2230.4
Price ($/ton)	818.2	200.0	1327.3
Gross returns	1728.4	827.3	2763.9
Net returns over TC	458.7	-427.2	397.5
Net returns over VC	1014.4	111.7	919.6
BCR	1.36	0.66	1.16
Grain yield (kg/ha normal)	1983.4	7323.6	2423.1
Net returns over TC	353.1	210.2	849.7
Net returns over VC	908.8	749.1	1371.7

* All the chickpea plots adopted improved cultivars

The benefit-cost ratio of chickpea is higher in case of chickpea when compared with competing crops such as tobacco and maize in Prakasam (Appendix 16.1). Among the seven study districts, farmers in Prakasam are more progressive and innovative when it comes to chickpea cultivation. Due to this, chickpea realizes the highest productivity in the country. Most here prefer to grow kabuli types which increase their gross revenue further. With all these factors in the background, chickpea was able to compete with tobacco and maize in the district. Relatively, chickpea needs less investment per ha and is also a suitable crop for mechanization. Even though tobacco competed very closely, it requires more labor units per ha.

Appendix 16.2. Competitiveness of chickpea in Kurnool district ($ per ha).

Item	Chickpea (201 plots*)	Sorghum (50 plots)	Sunflower (10 plots)	Coriander (2 plots)
Land preparation	56.5	64.5	53.8	20.9
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	44.7	35.7	12.8	0.0
Planting	20.4	26.8	23.8	2.1
Seed cost	101.0	11.5	31.2	10.3
Seed treatment	2.2	0.4	0.0	0.0
Fertilizer cost	86.7	91.3	74.3	27.1
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	11.5	18.6	17.4	5.5
Weeding	29.1	34.3	31.7	6.2
Plant protection	43.3	39.3	24.3	12.0
Irrigation	1.6	18.3	13.1	0.0
Watching	0.0	4.7	8.8	0.0
Harvesting	36.6	74.5	23.4	4.7
Threshing	32.0	49.7	27.8	0.9
Marketing	6.9	11.5	7.8	0.2
Total variable cost (TVC)	472.7	481.2	349.9	90.0
Fixed cost	347.9	367.4	307.6	100.0
Total cost (TC)	820.5	848.6	657.6	190.0
Grain yield (kg/ha actual)	894.1	2665.1	876.9	0.2
Price ($/ton)	727.3	290.9	545.5	0.9
Gross returns	680.0	744.2	480.4	11.6
Net returns over TC	-140.6	-104.3	-177.1	-178.4
Net returns over VC	207.3	263.0	130.5	-78.4
BCR	0.83	0.88	0.73	0.06
Grain yield (kg/ha normal)	1603.0	4038.5	1165.8	5.5
Net returns over TC	345.3	326.3	-21.6	71.8
Net returns over VC	693.2	693.6	286.0	171.8

* All the chickpea plots adopted improved cultivars

The competitiveness of chickpea in Kurnool district is analysed and presented in Appendix 16.2. Chickpea closely competes with sorghum in the district. However, the gross revenues per ha were much higher for chickpea when compared with sunflower and coriander. The impact of drought was conspicuous across all crops in the district during 2011-12. As per secondary statistics, chickpea has significantly replaced sorghum and sunflower crops in the district during the last two decades. Many of the sample farmers expressed that chickpea is relatively less risky and highly suitable for mechanization. Due to the recent increase in agricultural wages, farmers prefer less labor intensive crops.

Appendix 16.3. Competitiveness of chickpea in Anantapur district ($ per ha).

Item	Chickpea (70 plots*)	Sorghum (8 plots)	Sunflower (1 plots)
Land preparation	55.5	54.0	125.7
Seed bed preparation	0.0	0.0	0.0
Compost/animal penning	37.3	66.9	101.0
Planting	23.0	23.6	20.2
Seed cost	104.7	9.4	29.2
Seed treatment	2.5	0.0	0.0
Fertilizer cost	52.5	65.0	83.1
Micro-nutrient	0.0	0.0	0.0
Interculture	15.6	24.4	35.9
Weeding	22.6	27.9	52.1
Plant protection	37.7	11.4	60.2
Irrigation	0.9	0.0	0.0
Watching	0.0	23.0	0.0
Harvesting	30.2	65.3	0.0
Threshing	24.7	43.6	26.9
Marketing	5.4	11.1	4.5
Total variable cost (TVC)	412.5	425.6	538.9
Fixed cost	226.5	193.7	89.8
Total cost (TC)	639.0	619.3	628.7
Grain yield (kg/ha actual)	610.1	2126.7	370.5
Price ($/ton)	709.1	272.7	545.5
Gross returns	430.6	616.8	202.1
Net returns over TC	-208.4	-2.5	-426.6
Net returns over VC	18.1	191.2	-336.8
BCR	0.67	1.00	0.32
Grain yield (kg/ha normal)	1202.9	2223.0	617.5
Net returns over TC	235.8	-13.0	-291.9
Net returns over VC	462.3	180.7	-202.1

*Almost all chickpea plots adopted improved cultivars

The extent of substitutability/competitiveness of chickpea compared to other major postrainy crops in Anantapur district is presented in Appendix 16.3. As in Kurnool, chickpea here competes with sorghum. However, the gross revenues were higher in sorghum when compared to chickpea. Due to drought during 2011-12, chickpea in Anantapur experienced severe yield losses. However, when we examine the yields of both crops with average normal yields, chickpea performs better. It has substantially replaced sorghum and sunflower during the last two decades.

Appendix 16.4. Competitiveness of chickpea in Kadapa district ($ per ha).				
Item	Chickpea (78 plots*)	Black gram (4 plots)	Sorghum (5 plots)	Sunflower (5 plots)
Land preparation	69.4	57.8	69.6	58.7
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	19.3	0.0	0.0	21.6
Planting	21.2	24.3	28.3	25.5
Seed cost	113.8	23.1	18.1	35.0
Seed treatment	2.6	2.3	0.0	0.0
Fertilizer cost	88.1	82.0	117.4	97.4
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	14.9	14.8	24.8	6.3
Weeding	32.5	38.0	55.0	31.9
Plant protection	57.5	101.9	68.1	16.1
Irrigation	0.0	0.0	28.3	0.0
Watching	0.0	0.0	0.0	7.0
Harvesting	49.4	59.3	111.2	33.6
Threshing	44.2	42.2	91.0	20.8
Marketing	8.3	7.5	24.0	4.8
Total variable cost (TVC)	521.2	453.1	635.8	358.6
Fixed cost	285.0	263.8	332.3	233.5
Total cost (TC)	806.2	717.0	968.2	592.1
Grain yield (kg/ha actual)	1482.0	1128.8	3369.1	622.4
Price ($/ton)	727.3	709.1	236.4	618.2
Gross returns	1138.1	822.2	898.4	393.6
Net returns over TC	331.9	105.3	-69.8	-198.5
Net returns over VC	616.9	369.1	262.5	35.0
BCR	1.41	1.15	0.93	0.66
Grain yield (kg/ha normal)	1449.9	1111.5	3598.8	1017.6
Net returns over TC	248.3	71.2	-117.5	37.0
Net returns over VC	533.3	335.0	214.8	270.5

*Almost all chickpea plots adopted improved cultivars

The performance of chickpea in Kadapa district is presented in appendix 16.4. Chickpea strongly competes with other crops that enjoy high benefit-cost ratio values. The gross revenues per ha are significantly higher in chickpea than black gram, sorghum and sunflower crops. However, black gram closely follows chickpea when it comes to the benefit-cost ratio. The actual yields in the district are much closer to normal yields due to low impact of climatic aberrations.

Appendix 16.5. Competitiveness of chickpea in Mahabubnagar district ($ per ha).		
Item	Chickpea (10 plots*)	Maize (5 plots)
Land preparation	76.8	68.2
Seed bed preparation	0.0	0.0
Compost/animal penning	0.0	0.0
Planting	30.5	35.7
Seed cost	115.1	38.6
Seed treatment	5.0	0.0
Fertilizer cost	89.5	145.7
Micro-nutrient	0.0	0.0
Interculture	14.0	28.9
Weeding	40.2	45.8
Plant protection	46.9	28.1
Irrigation	0.0	28.8
Watching	0.0	0.0
Harvesting	18.9	55.6
Threshing	10.7	27.8
Marketing	2.2	10.9
Total variable cost (TVC)	450.0	514.1
Fixed cost	332.3	269.5
Total cost (TC)	782.4	783.5
Grain yield (kg/ha actual)	165.5	1980.9
Price ($/ton)	672.7	218.2
Gross returns	102.4	479.0
Net returns over TC	-679.9	-304.5
Net returns over VC	-347.6	-35.1
BCR	0.13	0.61
Grain yield (kg/ha normal)	1568.5	3811.2
Net returns over TC	272.8	48.0
Net returns over VC	605.1	317.5

*Almost all chickpea plots adopted improved cultivars

Appendix 16.5. analyzes chickpea performance in Mahabubnagar in relation to other crops. As discussed and highlighted in earlier sections, chickpea is severely damaged in the district due to the drought. The effect was conspicuous in both chickpea and maize. Under normal yields, chickpea strongly competes with maize with sizable net returns per ha.

Appendix 16.6. Competitiveness of chickpea in Medak district ($ per ha).		
Item	Chickpea (3 plots*)	Cotton (3 plots)
Land preparation	84.8	88.8
Seed bed preparation	0.0	0.0
Compost/animal penning	0.0	44.1
Planting	46.7	54.2
Seed cost	72.3	160.8
Seed treatment	0.0	0.0
Fertilizer cost	61.7	162.4
Micro-nutrient	0.0	0.0
Interculture	0.0	57.9
Weeding	43.2	55.4
Plant protection	41.3	127.9
Irrigation	0.0	0.0
Watching	0.0	0.0
Harvesting	62.8	187.8
Threshing	65.0	0.0
Marketing	15.9	19.2
Total variable cost (TVC)	493.7	958.6
Fixed cost	419.1	404.2
Total cost (TC)	912.9	1362.8
Grain yield (kg/ha actual)	1729.0	2200.8
Price ($/ton)	581.8	690.9
Gross returns	1018.9	1505.8
Net returns over TC	106.0	143.0
Net returns over VC	525.1	547.2
BCR	1.12	1.1
Grain yield (kg/ha normal)	1598.1	1939.0
Net returns over TC	16.9	-23.1
Net returns over VC	436.1	381.1

* Only sole plots considered for analysis

The detailed break-up of costs and returns per ha of chickpea cultivation in Medak district is presented in Appendix 16.6. Chickpea is closely competing with commercial crops such as cotton in Medak. Even though the gross returns per ha are much higher in cotton, the costs/investments per ha associated with it are also larger. In general, farmers prefer chickpea because of high net returns as well as lower investments per ha.

Appendix 16.7. Competitiveness of chickpea in Nizamabad district ($ per ha).		
Item	Chickpea (14 plots*)	Sorghum (4 plots)
Land preparation	82.5	78.3
Seed bed preparation	0.0	0.0
Compost/animal penning	0.0	0.0
Planting	29.4	45.3
Seed cost	75.6	7.8
Seed treatment	0.0	0.0
Fertilizer cost	59.4	43.1
Micro-nutrient	0.0	0.0
Interculture	6.1	0.0
Weeding	46.8	36.6
Plant protection	72.8	7.7
Irrigation	2.2	0.0
Watching	0.0	0.0
Harvesting	58.9	106.9
Threshing	54.6	56.0
Marketing	16.6	12.0
Total variable cost (TVC)	504.9	393.7
Fixed cost	391.3	325.6
Total cost (TC)	896.2	719.3
Grain yield (kg/ha actual)	1751.2	1538.8
Price ($/ton)	563.6	400.0
Gross returns	976.5	617.3
Net returns over TC	80.3	-102.0
Net returns over VC	471.6	223.6
BCR	1.09	0.86
Grain yield (kg/ha normal)	1864.9	2776.3
Net returns over TC	154.9	391.2
Net returns over VC	546.2	716.8

*More than half plots under improved cultivars

The competitiveness of chickpea in Nizamabad district is summarized in Appendix 16.7. The gross returns per ha were significantly higher for chickpea than sorghum. However, sorghum competes strongly with chickpea under normal yields in the district.

Appendix 17. Summary of welfare benefits across different category of farmers

Appendix 17.1. Break-up of total welfare benefits ($ million)

Item	Total All	Total AP	PRM-NA	PRM-A	PRM-SW	KUR-NA	KUR-A	KUR-SW	ANA-NA	ANA-A	ANA-SW	KAD-NA	KAD-A	KAD-SW	MED-NA	MED-A	MED-SW	NIZ-NA	NIZ-A	NIZ-SW	MAH-NA	MAH-A	MAH-SW	RAP-NA	RAP-A	RAP-SW
Total Welfare Change	711.7	358.9	0.0	6.7	71.1	-0.1	62.9	104.7	0.0	15.2	28.3	0.0	8.4	22.3	-0.9	9.5	0.0	-0.9	9.5	3.3	0.0	5.2	14.3	-2.7	2.3	0.0
Producer Surplus	228.8	353.3	0.0	6.6	70.2	-0.1	62.1	103.3	0.0	15.0	27.9	0.0	8.3	22.0	-1.1	9.3	0.0	-1.1	9.3	3.3	0.0	5.1	14.1	-3.1	2.2	0.0
Consumer Surplus	482.9	5.6	0.0	0.1	0.9	0.0	0.8	1.3	0.0	0.2	0.4	0.0	0.1	0.3	0.2	0.1	0.0	0.2	0.1	0.1	0.0	0.1	0.2	0.5	0.0	0.0
Adopters	606.0	358.7																								
Non-adopters	-377.2	-5.4																								

NA: Non-adopters; A: Adopters; SW: Switchers

About **ICRISAT**

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT is a member of the CGIAR Consortium

The **International Crops Research Institute for the Semi-Arid Tropics** (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, of whom 644 million are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented Development (IMOD).

ICRISAT is headquartered in Patancheru, Telangana, India, with two regional hubs and six country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. CGIAR is a global research partnership for a food secure future.

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